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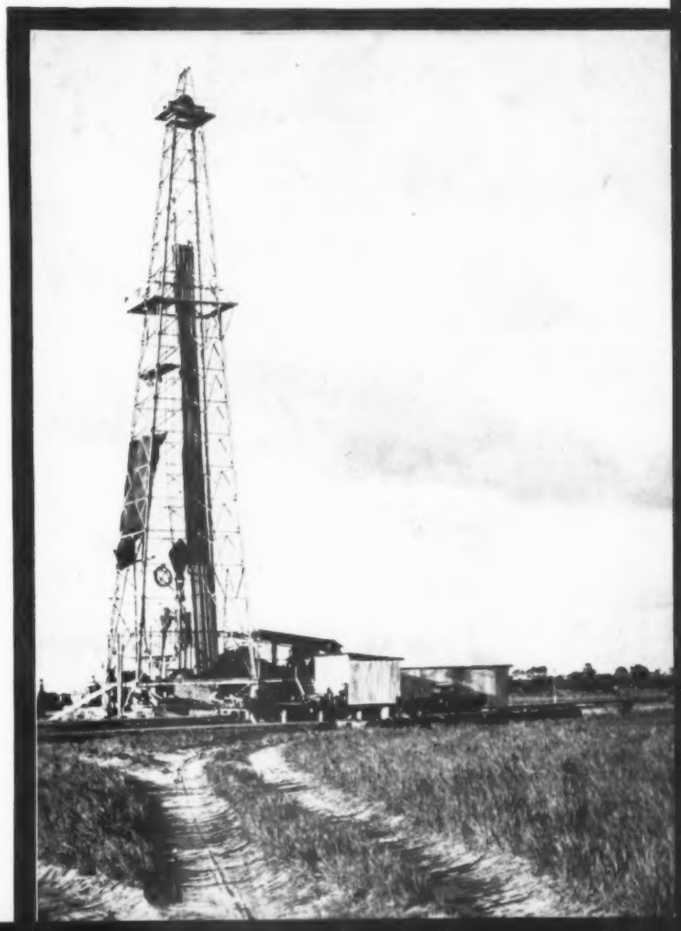

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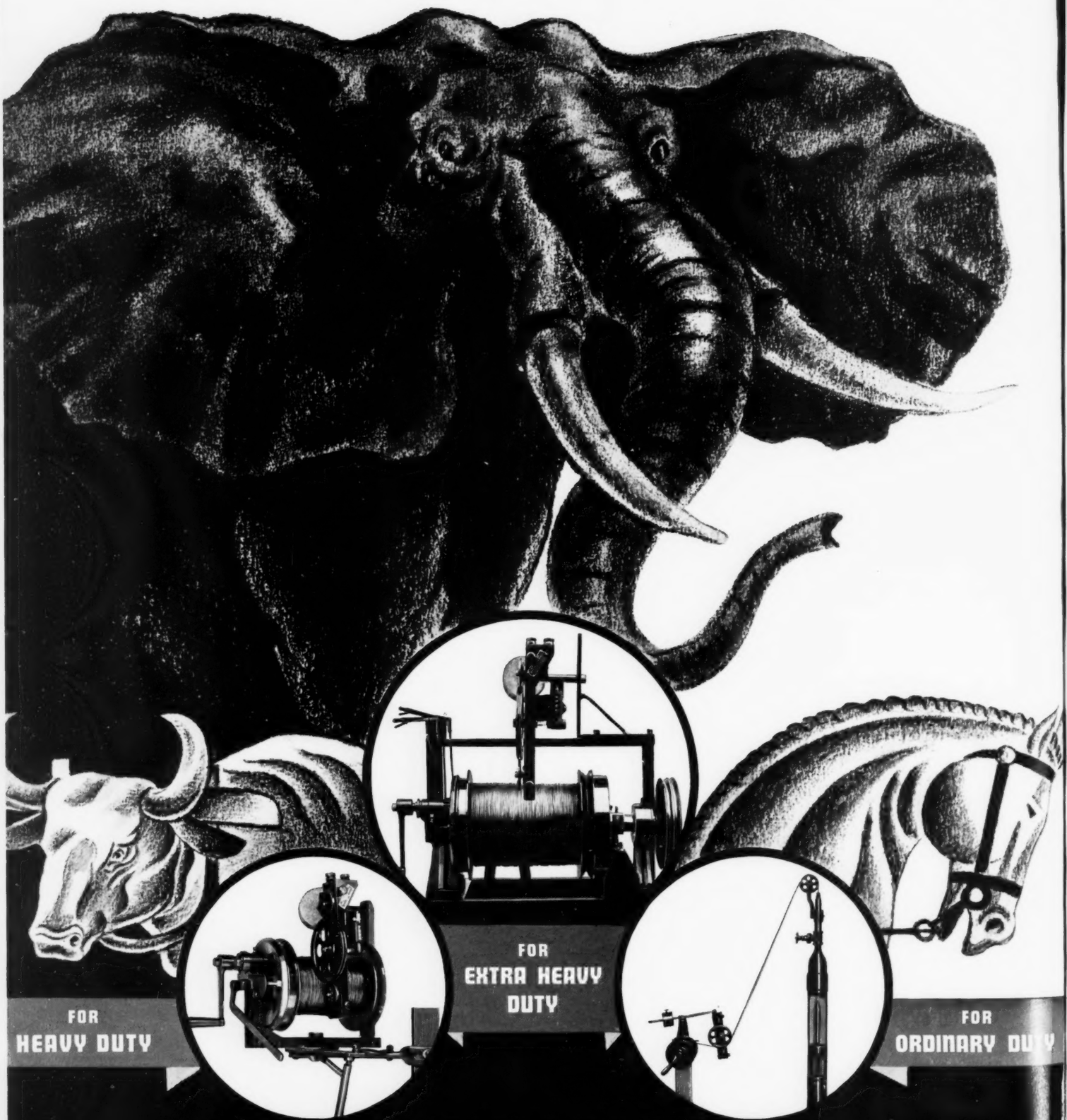

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WORLD PETROLEUM

VOLUME VII — **Editor, E. W. Mayo** — NUMBER 5

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By Robert Yarnall Richie

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PETROLEUM

Mexico's Oil Policy

MEXICO formerly ranked second only to the United States in the volume of its oil production. In the opinion of well-informed oil men it could regain that position, or one very near it, if physical and commercial considerations were the only limiting factors. Their belief is that Mexico possesses great undeveloped petroleum resources. Companies that have had long experience in Mexican operations would back their confidence by the expenditure of hundreds of millions of dollars for exploration and development, if they were convinced that they would receive protection for their investment and a chance to realize a fair return from any production that might be obtained.

It is generally admitted that the decline in Mexico's production and export of petroleum has been due to the enactment of laws that made it practically impossible for oil companies to replace failing fields by the development of new producing areas. Even greater uncertainty has resulted from the varying interpretations put upon these laws at various times under different administrations. Thus the companies which had the experience, resources and trade outlets needed to maintain Mexico's position as a producer and exporter of petroleum, never knew what would be the fate of new funds invested in the country, nor whether their properties might not be taken away from them under some arbitrary interpretation of the laws.

As was pointed out in an article written by a prominent Mexican authority and published some months ago by WORLD PETROLEUM, the heaviest loser under the uncertain policy of the past two decades has been the Mexican nation itself. It has lost a huge sum in export sales which would have brought hundreds of millions of dollars in cash or credit to the country. It has lost heavily in the esteem of other peoples, which is a far from intangible factor in these modern days. It has lost in taxation a sum that can be computed by tracing the shrinkage from $80,000,000 to $6,000,000 over a period of a dozen years.

Most important of all, the attempt to encourage nationalization of Mexican oil resources, which was the avowed purpose of the original legislation, has proved a failure, since the share of Mexican citizens in the country's petroleum industry has decreased rather than increased.

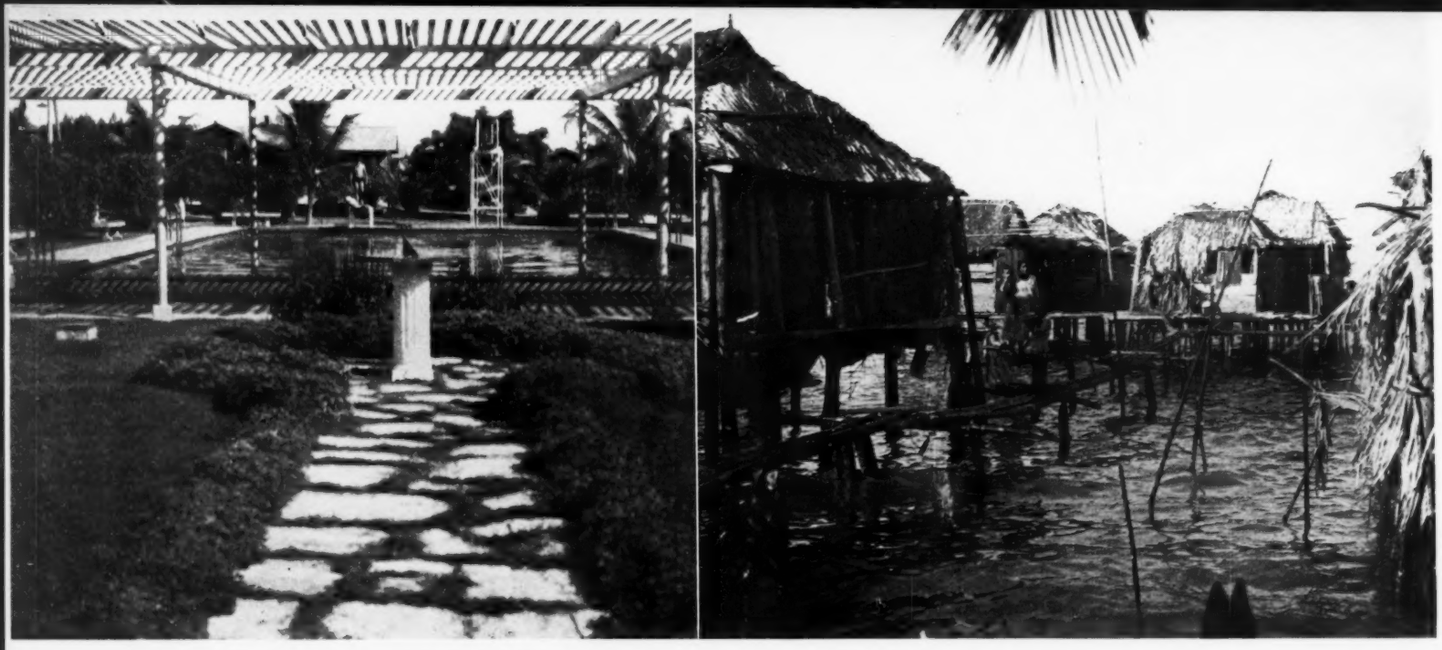
Nobody can question Mexico's authority to manage its affairs in its own way so long as it respects the rights of individuals and companies who have been encouraged to invest in the development of the country's resources, but it is within the scope of a journal that is interested only in the welfare and progress of the nations that possess great oil resources to point out the results of policies that have failed to produce the results anticipated for them. It is in no captious spirit, therefore, that we direct attention to the fact that while Mexico's oil revenues have dwindled with the decay of the industry, Venezuela, by following a somewhat different policy, now derives a greater income from petroleum than from any other source.

From time to time we have noted a disposition on the part of the Mexican government to adopt a more settled and satisfactory official course toward the oil industry, to discourage unwarranted legal attacks and to favor drilling development under proper restrictions. Unfortunately, these constructive acts have been contemporaneous with labor disturbances apparently fomented by the most radical and least responsible representatives of the labor movement. Oil companies, already paying higher wages than any similar group of companies in Mexico and providing extra facilities in the way of housing, sanitation and hospital care, have been made the objects of special attack and subjected to demands which, if enforced, would make continued operation impossible.

Drilling Developments

EVERY year sees a marked improvement in drilling technique, the incorporation of methods that last year were in the experimental stage, the beginning of new experiments that a few years hence will be standard practice. Not for many years has the result of improved technique in drilling and production been so important to the world as in the present year. Petroleum resources are far from being exhausted, even in the United States; but the day of prolific fields coming one on the heels of another and depressing prices to unbelievably low levels may well have passed. Future discoveries will depend to an increasing extent on all the aids to exploration that science can furnish.

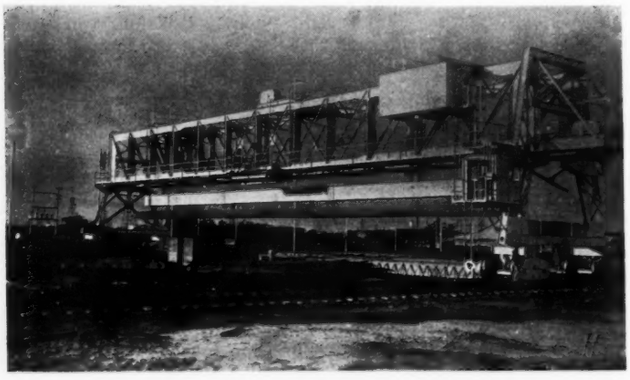
With growing evidence of the importance of improvements in drilling and production technique and equipment, WORLD PETROLEUM deems it timely to present a review of the present status of this art. The distinguished list of authors who have contributed articles to this issue assures the reader of the soundness and importance of the subjects covered herein.



Cooperative Policy to be Continued by Venezuelan Executive

President Contreras Emerges from the April 19 Elections with a Policy of Liberalization for Political Organization and Cooperation with Oil Companies in Development of Resources.

Above: contrast between conditions in native villages and oil company camps is well illustrated above. On the right is Santa Rosa on the shore of Lake Maracaibo; on the left is a view of the swimming pool of the Lago Maracaibo terminal. Left: a fifty ton Gantry crane moving a concrete pile to storage space.



THE election on April 19 of President E. Lopez Contreras as Chief Executive of Venezuela, was of more than usual interest to officials of international oil companies. The principal reason for this unusual interest resulted from the fact that President Contreras will be the first chief executive in Venezuela for the past two generations who will not be directly responsible to the late great dictator of Venezuela, General Juan Vincent Gomez. Moreover, following the death of General Gomez news of social and political unrest reached the United States and Europe in a fragmentary manner from which it was difficult to determine if this reaction resulted simply from the removal of political restraint that has existed in Venezuela for over twenty years, or if it portended important social and political changes.

Questions immediately arose as to the ability of General E. Lopez Contreras to control all parties in Venezuela; and as to his attitude toward international capital invested in the development of Venezuelan natural resources.

It has now become apparent that no question exists as to the ability of General Contreras to control the country of which he is chief executive. His past record, the attitude of the nation to the General when other members of the late Gomez cabinet were being driven from the country and their property destroyed or confiscated, and the practically unanimous vote cast for General Contreras on April 19th, serve to dispel any doubt as to his control of even the most radical elements in the country as well as his solid backing by the more conservative party.

The new President's attitude is well expressed by his intention to retain certain benefits from the policy pursued by the former

Scene at native village "Santa Rosa" on Lake Maracaibo in Venezuela.

administration while discarding that administration's repressive policy toward free speech or opposition to the acts of the government. President Contreras plans to permit far greater freedom on the part of the electorate and at the same time to continue the policy of cooperation toward the oil interests operating in Venezuela which has resulted in so sound a financial situation for the Venezuelan treasury.

The recent situation within Venezuela represented a natural reaction against the long policy of political repression that had existed under the administration of General Gomez. All political parties which had for some twenty years been completely inarticulate clamored for an opportunity to be heard. Conditions were further complicated by the presence of professional agitators, anxious to take advantage of what they considered a major political upheaval. General Contreras endeavored conscientiously to permit all factions to be heard while maintaining a sane and balanced form of government and avoiding radical changes in policy. As the situation settled down, it became apparent that the people of Venezuela were opposed to any sharp swing to the left on the part of the government. Armed with this knowledge President Contreras emerged from the elections of April 19 as the unanimous choice of the Venezuelan people.

In the face of the contrast presented by the results of Mexico's policy of hampering and restricting the development of her natural resources by outside capital, followed by a steady decline in the importance of Mexico as an oil producing nation and the loss of important benefits by the Mexican government with the fortunate position of Venezuela which is perhaps the only important country in the world that is without foreign debt and practically no internal debt, largely as a result of the cooperative policy pursued by the government with international oil companies in the development of her resources: such a contrast left no alternative to the new administration in formulating a policy toward petroleum development. Revenue from petroleum in Venezuela now exceeds all other sources of government income. The social and medical work of the international oil companies in the more isolated sections of the country sets a standard that has yet to be equalled by the government, although steps are now being taken to provide better facilities in this direction by the new administration. In many sections of the country, the roads and hospitals provided by the oil companies for public use are the only roads and hospitals that exist. There is very little evidence of ill will toward the oil companies, on the part of the public. The people, in fact, recognize the benefits they derive from these operations, and that without them the country would be far more backward, outside of the more important cities, than it is. The demand for improved standards of living, in fact, often takes the form of requests to bring public facilities up to the standards maintained by the oil companies and available even for public use where such provision is practical.

Professional agitators have actually appeared at a number of workers' meetings and have attempted to organize labor into united opposition toward established authority. Lately, however, the Venezuelan workers have demonstrated their inherent mental balance by ejecting, violently in a number of cases, these agitators whose extremely radical claims did not appeal to the workers.

The confidence of the oil companies operating in Venezuela, in the future of the country and the sound policy of the present administration is displayed by increased expenditures for drilling and development as well as the construction of permanent camps, hospitals, roads and schools.

▼

German Benzol Production

GERMANY increased its benzol output more than 30 percent last year, due to improved recovery methods and to greater activity in the coke industry which produces benzol as a by-product. Approximately 400,000 metric tons of benzol were obtained from coke operations in 1935, according to estimates, and an additional 30,000 tons were recovered from gas plants.

Barco Concession Changes Hands

Socony-Vacuum Corporation and The Texas Company to Acquire Controlling Interest in Famous Colombian Concession, Named for Gen. Don Virgilio Barco in 1905.

ANNOUNCEMENT was made in mid-April that Socony-Vacuum Oil Co. Inc. and The Texas Company were jointly negotiating for the purchase from South American Gulf Oil Co. of the latter's controlling interest in the vast tract known as the Barco concession in Colombia. The original area comprised in the concession amounted to 1,300,000 acres from which 500,000 acres are to be selected as a permanent holding after survey and exploration.

The lands covered by the concession lie between the boundary of Venezuela and the most northerly spur of the eastern range of the Andes, about 250 miles from the coast. The development work already done indicates the existence of an important oil field. Eleven wells have been drilled and show substantial production of oil averaging 40 deg. gravity or higher. It is announced that the new owners will proceed at once to push forward the work of exploration and drilling. The concession runs for fifty years from 1931.

The Barco concession gets its name from Gen. Don Virgilio Barco, to whom the concession was granted by the Colombian government in 1905. The greater part of the region was, and still is, a dense jungle, unexplored and inhabited by the fierce Motilone Indians, who made life extremely hazardous for all strangers who entered their domain. The prospect of locating and developing oil in such an area would have discouraged anyone less dauntless than Gen. Barco. He located a number of seepages, however, and dug some shallow wells from which he obtained enough crude to operate a small and primitive refinery.

Seeking to expand his operations Gen. Barco came to New York and presently enlisted the support of a group organized under the name of the Carib Syndicate who already were interested in Colombian exploration. A party was outfitted and sent to the concession. A well was drilled at Rio de Oro to 890 feet, disclosing a flow of oil estimated at over 1,000 bbl. per day. Owing to the difficulty of transporting heavy equipment to the site, which could be reached only by water through Venezuelan territory, the well was closed in and operations were suspended for several years.

In 1917 the concession was acquired by the Colombian Petroleum Co. through a subsidiary and in 1925 a controlling interest in the Colombian Petroleum Co. was purchased by the South American Gulf Co., wholly owned subsidiary of the Gulf Oil Corporation. This placed the property in the hands of interests with ample resources to carry forward the work of development but the Colombian government issued a decree voiding the concession on the ground that its original provisions had not been complied with. This led to suits in the Colombian courts to establish the rights of the various parties involved. These suits dragged on for several years.

In 1930 the claims were adjusted and a new agreement was made by which the Colombian Petroleum Co. and South American Gulf were to expedite the survey of the property, and after proper geological examination were to select 500,000 acres for actual development. It was provided also that when production reached 20,000 bbl. daily the South American Gulf should build a pipeline to the coast, some 250 miles distant, and when production had risen to 28,000 bbl. one of the two companies was to construct a refinery.

During the past few years the work of exploration has been pushed forward under the direction of the Gulf interests and eleven wells have been drilled. Nine of the wells have been put down in the Petrolea section, near the early Barco explorations, where the effort has been made to determine the possibilities of production at different levels. Wells have been sunk south of the original well at Rio de Oro but a great part of the area remains still to be explored.

On the Venezuelan side of the Petrolea Ridge, directly across from the Barco, lies the important field of the Colon Development Corporation which has been producing high grade oil for many years. The same formation which is found in this field has been shown to extend southwestward through the Barco territory.

The reason assigned in oil circles for the present transfer of ownership is that the Gulf Company does not require the oil that it might obtain from the Barco field while Socony-Vacuum and Texas have outlets for it in their export marketing operations. The action of the United States in placing a tariff on oil makes its importation into this country impracticable.

In connection with the purchase of Gulf's Barco interests it was announced that Socony-Vacuum had acquired a majority of the stock of Equatorial Oil Co., together with the Carib Syndicate's claim of $203,569 against the Equatorial Co. The Equatorial's holdings consist of land in the Magdalena valley in Colombia on which no development of any extent has been attempted.

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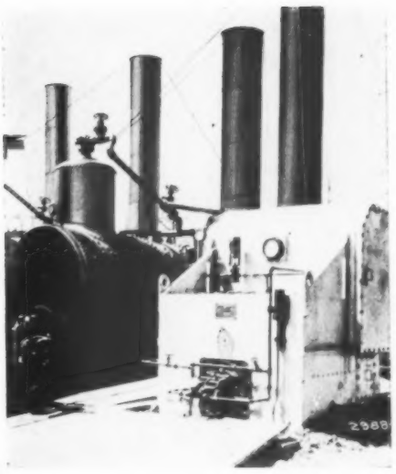
Petroleum-Vademecum

PETROLEUM-VADEMECUM, published by Technical Advisor h.c. Engineer Robert Schwarz (XIth edition 1936, Volumes I and II). The new edition of this seasoned German handbook for oil men has been largely re-written and much new material has been added. There is a large section on oil tariffs in different countries; extensive tables on oil production, refining, imports, exports and consumption of oil products are given. The section on drilling engineering has been much enlarged to contain the A.P.I. tables as well as German standards for rigs, drilling tubes, pipelines, tool joints, wire ropes, etc. There has been added a new department on nomenclature, giving the equivalent names of oil products in many countries. There is also what is intended as a complete list of all the petroleum refineries in the world. Although most of the text is in German the important headings of reference tables are given also in French and English.

Steam Power Efficiency

Conservation of Heat Has Long Been Appreciated as an Important Consideration in Permanent Power Plants—But Is Only Recently Receiving Proper Attention on Drilling Rigs.



Separately-fired superheater built by Foster-Wheeler Corporation.

STEAM has been used as the source of motive power on drilling rigs since oil was first produced from drilled wells. Until recently no sincere attempts have been made to conserve heat either at the boiler plant or in connection with the prime movers using the steam. If the same had been true with stationary steam power plants we would still literally be in the dark ages as the cost of electric power would be prohibitive. There are no sound basic reasons why the major improvements looking to heat conservation in stationary steam power plants cannot be applied to the portable steam power plants used for drilling oil wells. It is true that because of limitations as to simplicity, portability, and the type of work to be done, the drilling rig power plant cannot include all of the refinements of the high efficiency stationary plant but the basic principles can be applied without sacrificing simplicity, portability, etc. The following are the major subjects being dealt with in this regard by progressive manufacturers and users of drilling machinery today:

1. **Feedwater heating.**
2. **Superheating.**
3. **Slush Pump Prime Mover.**
4. **Rotary Prime Mover.**

Feedwater Heating

THE practice of heating the feedwater in the drilling rig boiler plant has been followed more or less indifferently for the past several years. The equipment used usually consists basically of a coil of pipe in the discharge line from the feed pump, this coil being placed inside a large pipe or shell to which exhaust steam from the pumps and engines is admitted for heating the water by conduction. This is known as the closed type of heater. If sufficient surface for heat transfer is provided to heat 20,000 lb. of water per hour or more to 200 deg. F., the closed heater becomes very large and cumbersome. Actual temperature readings taken in the field indicate that the heaters of this type generally in use not only are not large enough when originally made but also that their efficiency is rapidly reduced by scale and other insulating coatings which form both on the inside and the outside of the coil. It is very unusual to find feedwater temperatures above 130 deg. F., in heaters of this type.

One manufacturer has placed on the market a combined feed pump and heater unit which utilizes the same principle as the jet condenser for heating the feedwater. This is known as the open type heater and in it the cold feedwater as it is sprayed through a spring loaded valve comes into direct mixing contact with exhaust steam at a pressure of approximately 10 lb. per sq. in. gauge. This heater raises the feedwater to a temperature of approximately 210 deg. F., which is within 15 deg. F., to 25 deg. F., of the temperature of the exhaust steam in the heater chamber. The heater is of sufficient capacity to produce these results in a boiler plant developing 800 boiler horsepower. This type of heater has been used by the major railroads on locomotives for many years. Feedwater heated to 210 deg. F., requires 13 percent less heat to convert it into steam at 250 lb. per sq. in. gauge than does 55 deg. F., feedwater.

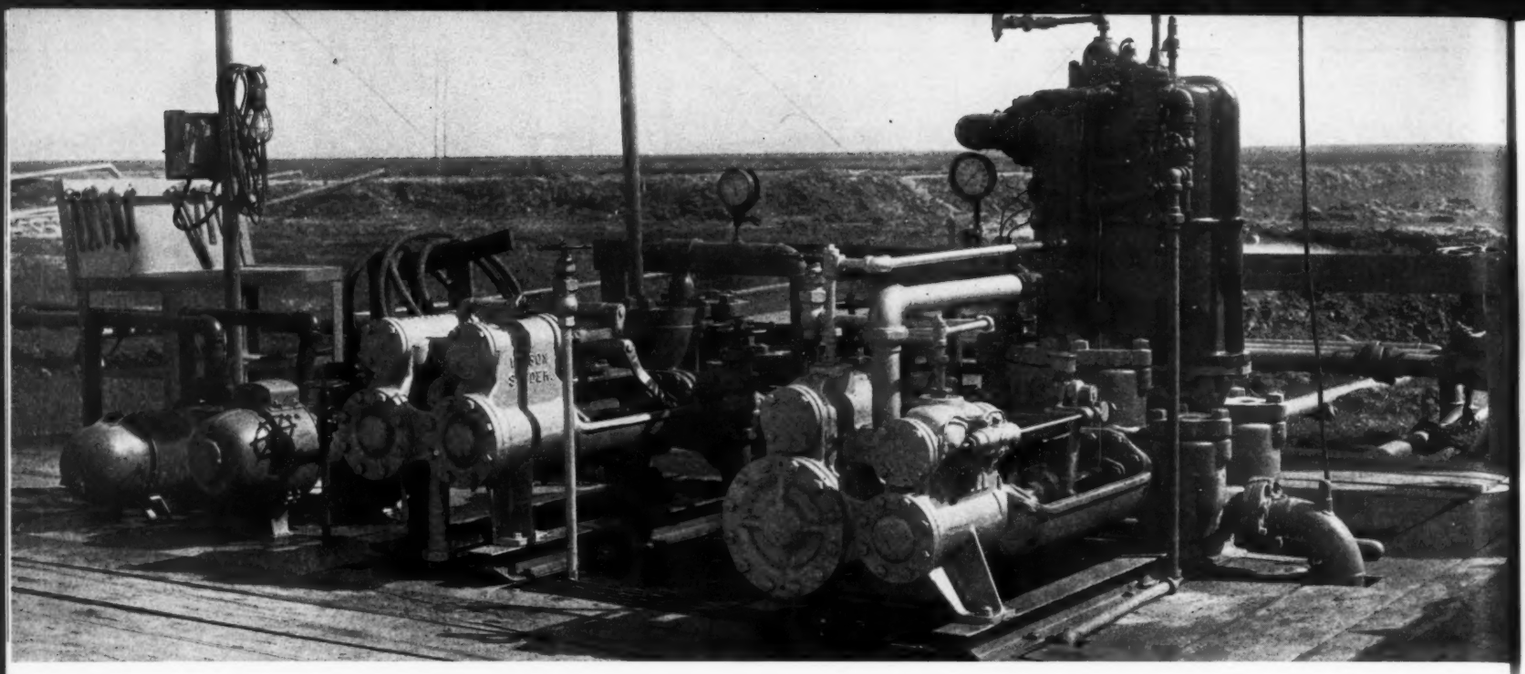
There are other advantages resulting from the use of the open type feedwater heater which are not related directly to heat conservation but which result in pronounced operating economies. In this type approximately 15 percent of the total steam generated is condensed in the heater and returned to the boiler as distilled water, thus reducing the raw water used by that amount. The result is cleaner boilers.

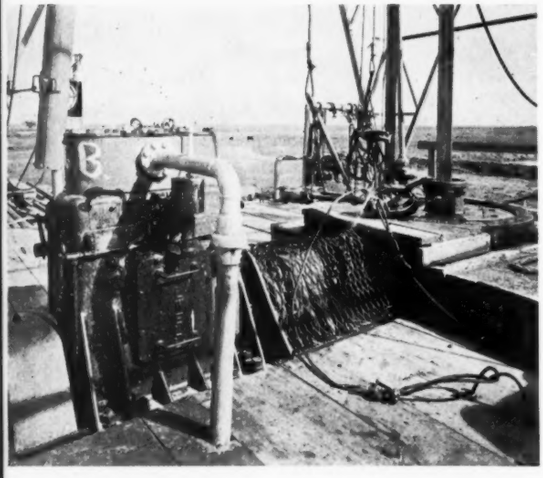
The elements of temporary hardness in most feedwater are precipitated at about 200 deg. F., and with the open type heater a portion of these precipitates forms scale in the heater chamber and the remainder passes into the boilers as a sludge which does not scale the tubes but settles into the water legs from which it is blown out. Scale in the heater chamber of the open type heater does not reduce the heater efficiency until it has built up sufficiently to interfere with the operation of the float mechanism, whereas in the closed heater a relatively thin scaling of the coil is very detrimental. The cleaning of the open type heater is very simple and easy to perform as the heating chamber can readily be removed from the feed pump and cleaned through large openings provided for that purpose. Scale deposited in the heater chamber is eliminated from the boilers. This results in cleaner boilers.

Water heated to approximately 200 deg. F., liberates any free oxygen which may be present. This oxygen is vented from the heater chamber through an opening provided for that purpose. Free oxygen in water fed to boilers causes pitting and the open type heater eliminates this condition and makes for longer boiler life.

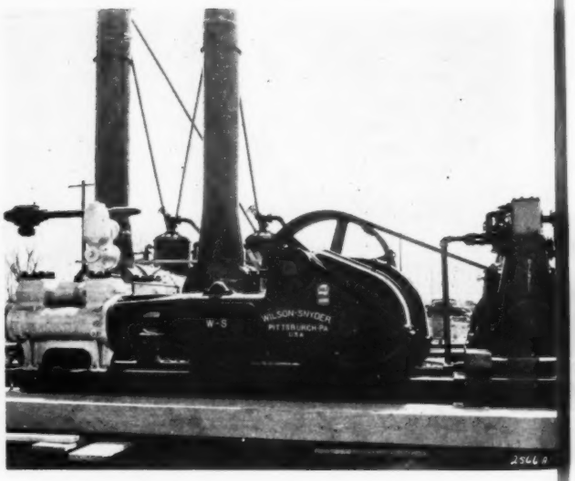
Superheating

FOR the past four or five years superheating equipment has been available to drilling operators in two forms. The first is of the built-in type in which special superheating tubes are built into the boiler, replacing some of the regular evaporating tubes and the second is of the separately fired type and consisting of an entirely separate unit which is placed in





At the top is a photo showing the right side of a feedwater heater of the open type, as built by Oil Well Supply Co. The Oil Well drilling unit on the left has a separate engine which is used for driving the rotary table, while the steam-driven power slush pump on the right has an engine built by Oil Well Supply and a Wilson-Snyder pump.



series in the main steam line leading from the boilers to the rig.

The specific volume (cu. ft. per lb.) of dry saturated steam at 250 lb. per sq. in. gauge is 1.745 cu. ft. per pound. The specific volume of steam at 250 lb. per sq. in. gauge superheated 100 deg. F., is 2.046 cu. ft. per pound. There is, therefore, an increase in volume due to 100 deg. F., superheat of 17.5 percent.

The total heat content of saturated steam at 250 lb. per sq. in. gauge is 1201.1 B.T.U. The total heat content of this same steam superheated 100 deg. F., is 1264 B.T.U. or an increase of 5.3 percent. Thus (for any given amount of water evaporated), by increasing fuel consumption 5.3 percent, we add 17.5 percent to the volume of the steam when superheating it 100 deg. F. Stating the matter conversely, the evaporation required of the boilers for a given volume output becomes 85 percent of that required for saturated steam and the fuel burned under the boilers becomes 85 percent of that required for saturated steam. The fuel used in the superheater must be taken into consideration and this results in a net fuel saving of approximately ten percent.

The use of superheated steam results in other notable operating improvements on a drilling rig. With saturated steam a very noticeable amount of condensation occurs in the long steam line running from the boiler plant to the rig. This condensation is entirely eliminated under ordinary conditions when superheat of 100 deg. F., is used. The machinery operates more efficiently, lubricates more effectively and responds to heavy demands more promptly when supplied with dry or slightly superheated steam.

In the built-in type of superheater, it is impossible to control the amount of superheat obtained. With the separately fired superheater now offered by one manufacturer which has a rated capacity of 15,000 lb. of steam per hour at 100 deg. F., superheat, it is possible to maintain automatically a constant steam temperature regardless of the quantity of steam generated up to the rated capacity of the superheater plus a reasonable overload. The main steam piping is usually arranged for by-passing the separately fired superheater so that it can be out of service if desired. This is not possible with the built-in type.

Slush Pump Prime Mover

THE direct acting duplex steam end usually used for driving the fluid end of the slush pump is unavoidably most uneconomical in the use of steam. This is true because with the direct acting pump valve gear no provision can be made for cutting off the admission of steam prior

(Continued on page 248)

Electric Power for Drilling in Jungle or Desert

Advantages of Flexibility Suggest the Use of Electricity for Drilling Power—Some Considerations that Affect Choice of Layout and Arrangement.

By W. G. Taylor

Industrial Engineering Dept.
General Electric Co.

THE ingenuity of oil men and engineers has been freely exercised in providing a variety of ways of utilizing diesel-electric drive for rotary drilling rigs. In both the mechanical and electrical layouts there are several practical arrangements possible, and each has its advantages as well as certain disadvantages. No particular arrangement seems to have been so outstanding as to have the preference of all purchasers.

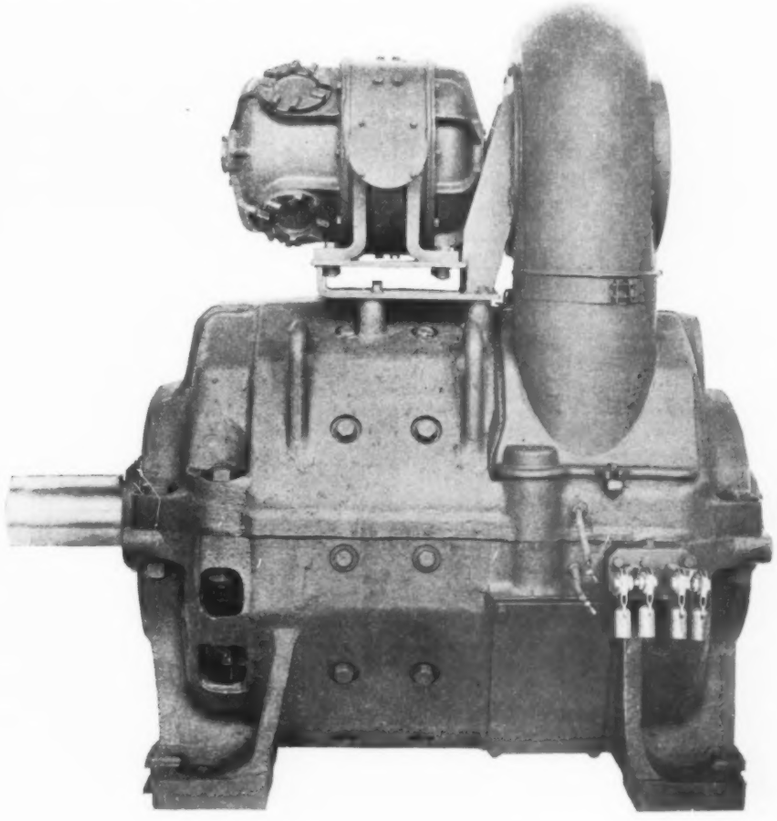
A diesel-electric drive consists essentially of a draw-works motor, one or two mud-pump motors, and sometimes a separate rotary-table motor, with electric power supplied to these by two or more diesel engine-driven direct-current generators and the necessary exciters. This form of rotary-rig drive is not confined to the use of diesel engines, as any form of internal-combustion engine may be used, but diesels have so far been the most popular. The motor speed is controlled by varying the voltage of the generator, requiring separate excitation for both, and the generator voltage not only is changed manually by varying the strength of its field, but also varies automatically with the load current, decreasing as the current increases. This latter characteristic limits the maximum load, thus protecting the engine against stalling, and also permits the motor to be loaded down to its stalling point and enables it to pick up speed again when the load is reduced. When the load is light, such as when hoisting the empty hook, this characteristic automatically results in a high generator voltage and consequently a high motor speed.

In its simplest form a full electric drive requires two generators, one to supply power to the draw-works motor or rotary-table motor for drilling, and the other to supply power to the mud-pump motors. The generators are combined to feed the draw-works motor for coming out of the hole and going back in with the drill pipe, and for handling casing. It is desirable to have a separate engine for each generator, so that power will always be available for coming out of the hole in case of failure of one engine.

Fig. 6.—Separately ventilated, protected draw-works motor designed for heavy duty.

One of the most successful mechanical connections from the motors to the mud pumps is V-belt drive, with a separate motor for each pump. The draw-works motor is usually coupled to a gear unit, with a chain drive from the latter to the jack-shaft of the draw works. In a few cases V-belt drive has been used from the draw-works motor direct to the jack-shaft, but is not so popular, because of the heavy shock loads to which it is subjected and the high stresses on the motor shaft and bearings if a third motor bearing is not used. The scheme of using a separate motor for the rotary table is too new to have demonstrated whether V-belt drive, chain drive or direct connection through a gear unit is best, but it seems likely that any one of these will meet the power requirements.

With reference to the engines, generators and exciters, there is a considerable



latitude of choice available in the mechanical and electrical layouts, but it is scarcely possible to consider them independently, for the former depends largely on the latter. The generators and exciters, however, may be classified in general as direct connected to, or V-belt driven from, the engines.

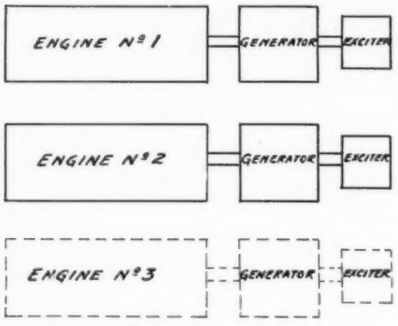
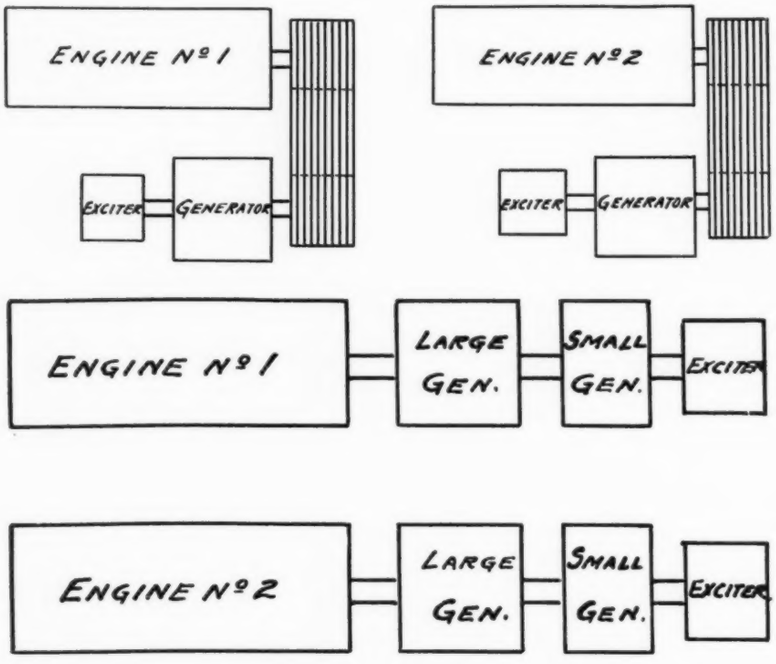


Fig. 1.—Duplicate generators and exciters direct connected to engines.

Fig. 2.—Duplicate generators and exciters V-belt driven by engines.

Fig. 3.—Large and small generators and exciters direct connected to engines.



From several standpoints direct connection, as illustrated in Figure 1, is preferable. Each engine-driven unit is mechanically independent and self-supporting, and requires no elaborate foundation supports of steel or timbers to maintain alignment or keep belts tight. Belt maintenance is eliminated. In the largest capacities required for deep drilling, lengths and weights of the generating units are within the capacities of available trucks and trailers for transportation. Should shorter and lighter units for a given total capacity be desired, three instead of two units may be used on a rig, using two for power to the pumps and the third for power to the rotary table during drilling, and transferring the power from one of the first two to be combined with that of the third for hoisting drill pipe. This leaves one unit available for power supply to one of the pumps for mixing mud, or for keeping the hole full of mud as a precaution against a blow-out, when the pipe is pulled. As many as five generating units are being used in a similar way on a single rig, thus affording great flexibility in switching generators from one group to the other and in the operation of only enough units to meet the power demands of the work immediately at hand.

There are disadvantages to the purchaser as well as to the electrical manufacturer in direct connecting generators to engines running at speeds under 1200 rpm, as nearly all of them do. The lower-speed generators are more costly, and it is not practicable for the manufacturer to carry in stock special drilling generators for the great variety of speeds of diesel engines now on the market. From this standpoint at least, V-belt drive, as illustrated in Figure 2, is more attractive; 1200 rpm generators can then be supplied for any speed of engine. This splits the unit into lighter and shorter sections for transportation, which may be desirable in some cases, but requires a substantial sub-structure for alignment and means for tightening belts, and adds belt maintenance as an item of care and expense.

Thus far the discussion has been with reference to individual generating units, with no means of balancing the loads on the engines during the actual drilling operation, when the pumps may take as high as 250 hp and the rotary table may require only from 50 to 100 hp, and rarely over 125 hp. One engine may thus be fully loaded and the other only half loaded or less, for hours at a time, and their resulting useful life will not be the same. An electrical layout which is used on several equipments was devised to balance the loads on engines with direct-connected generators, and the same result has been accomplished by a further development of the arrangement with V-belt drive. These two schemes have also been combined.

The electrical method, illustrated in Figure 3, is to use a large and a small generator coupled to each of the two engines. Power from the two large generators is combined to supply the pumps and from the two small generators to supply the rotary table. For hoisting drill pipe and handling casing, power from the two large generators is switched from the pumps to the draw-works motor, and the two small generators are left idle. With this scheme, each engine carries half the total load at all times. This arrangement has a somewhat higher first cost, but on the other hand permits one engine to be shut down and all the load carried on the other when the duty is light, such as in shallow territory or in the early stages of drilling in deep territory.

The V-belt arrangement, illustrated in Figure 4, devised to balance the load on the engines, is to couple two duplicate generators together and drive both by V-belts from each engine. With a suitably designed layout the generators can be uncoupled, and either of them driven by one engine in case of failure of the other engine or generator. When combined with the scheme of using large and small generators, this layout becomes one large and one small generator coupled together, as in Figure 5, and V-belt driven by two engines. The large generator supplies the pumps and the small generator supplies the rotary table with power;

the two generators are connected in parallel to supply their combined power for hoisting drill pipe. This arrangement has the advantage of using only two generators, with neither idle during hoisting, and the load balanced on the engines at all times. Clutches are provided so that either engine may be unclutched at will. Like all arrangements with belt drive, however, a suitable sub-structure is necessary and belt maintenance must be considered.

These are the fundamental arrangements obtainable with diesel-electric drive for drilling rigs. Several other variations are possible, such as the use of a third generating unit as a spare, which may also be used for independent operation of the second pump. Another is the use of three engines instead of two, belted to a generating unit with coupled generators. Still another is the use of only one generator belted to the engines and supplying power to only the draw-works motor, in which case the pumps are belted direct to the engines or to an extension of the generator shaft. This latter arrangement is often considered for the purpose of reducing the first cost. It gives the desired flexibility of control to hoisting operations, and economical, though not so flexible, pump drive.

The exciters may be driven in several ways. The exciter serves as an auxiliary generator of power for excitation of generators and motors, for the motor-driven blowers used to ventilate the drilling and mud-pump motors, for the mud-screen and wash-down pump motors, for the rig-lighting system, and sometimes for other auxiliary motors. It is therefore a machine of considerable capacity, usually from 15 to 30 kw. Two exciters are preferable, each at least of sufficient size to supply all the auxiliary power necessary to get the drill pipe out of the hole in an emergency.

When a generator is coupled direct to each engine, the exciter is usually coupled to the generator as in Figure 1. When the engine is coupled to both a large and a small generator, the exciter may be located on the outer end illustrated in Figure 3, but if the complete unit is thus undesirably long, the exciter may be mounted on top of the small generator and V-belt driven from an extension of its shaft. This makes a compact and easily handled unit. With belt-driven generators, the exciters are usually coupled to an extension of the generator shaft as in Figures 2, 4, and 5.

Another arrangement occasionally considered is to drive one of the exciters by an auxiliary engine and let it serve as a spare unit, with all load normally carried on the other exciter. The spare exciter is then used to furnish power for electrical cranking of the main engines, by driving one of the main generators as a motor. This eliminates the necessity of an air-starting system, as the auxiliary engine may be started by hand cranking or by a battery-operated cranking motor, as on automobiles.

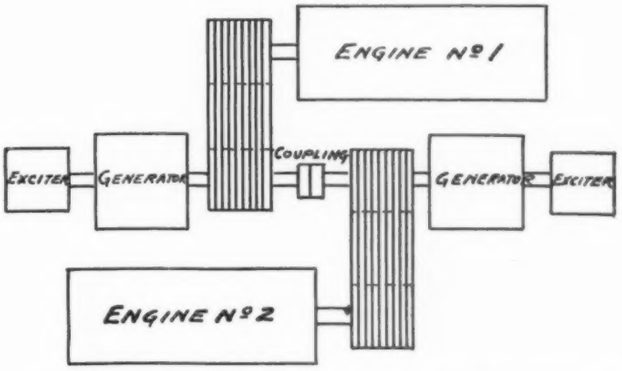


Fig. 4 (above).—Duplicate coupled generators and exciters V-belt driven by engines.

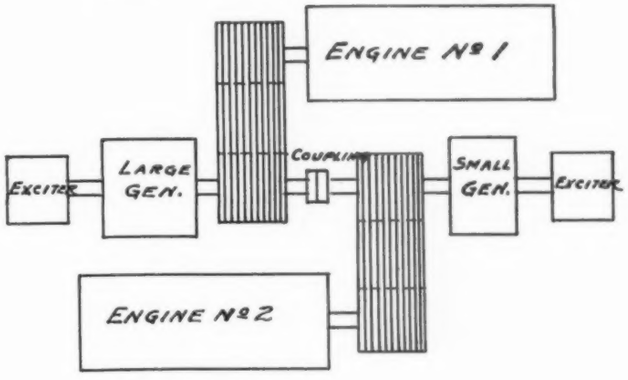


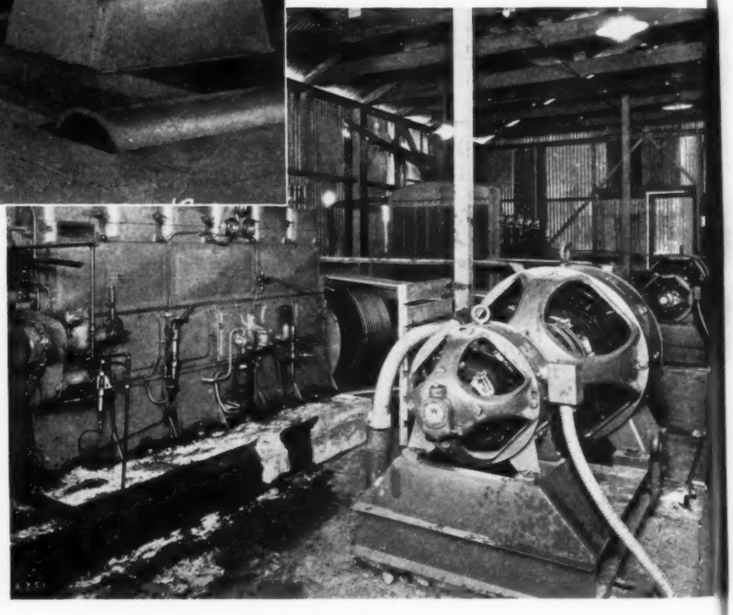
Fig. 5 (below).—Large and small coupled generators and exciters V-belt driven by engines.

It will be obvious that the decision as to which mechanical and electrical arrangement will best meet the requirements of any particular drilling-rig problem must rest on a consideration of the following factors:—

(a) First cost of equipment.
(b) Overall length of generating unit.
(c) Weight of heaviest unit to be transported.
(d) Cost and time required for erection.
(e) Proportion of load on each engine.
(f) Desirability of operating a pump while coming out of the hole.
(g) Maintenance of belts and clutches.
(h) Adaptability of generators to engines of various speeds.
(i) Number of renewal parts desirable to carry in stock.

This discussion would be incomplete without some attention given to the mechanical construction of motors for rotary drilling service.

The draw-works motor is subjected to heavy mechanical shock loads when jaw clutches are engaged and heavy loads of pipe and casing are picked up, and the service is also severe due to the whipping of slack and worn draw-works chains and the taking up of this slack on reversals. This service warrants the use of oversize shafts, heavy-duty bearings, and motor frames and windings of the sturdiest construction. Frequent reversing of the motor makes it highly desirable that the armatures be relatively small in diameter and therefore with low stored energy. To meet these requirements most satisfactorily without encroaching to a dangerous degree on the factors of safety in the mechanical design requires motors (Fig. 6) specially designed for such service as illustrated on page 229. While the mud pumps may not require as sturdy a motor as the draw-works, these motors are often all duplicates, thus making them interchangeable.



Left: Modern Westinghouse National Superior diesel-electric drilling unit, consisting of one generator force ventilated with a capacity of 175 k. w. cog belt connected with clutches, at Fair View, Oklahoma. Below: first direct connected variable voltage diesel-electric unit manufactured by Westinghouse Atlas Imperial for Standard Oil Company of California in 1927, and now operating in New Mexico.

Diesel Electric Drilling

By E. J. Herzog

Westinghouse Electric International Co.

For drilling the isolated well one of three methods is generally used, steam, straight diesel or diesel electric. The use of steam for drilling power has already been discussed. The straight diesel or full mechanical drive compares more directly with the diesel electric drive in respect to adaptability for drilling the isolated well. Both methods should be considered from all angles for each has its advantages and disadvantages which will be brought out more fully in this article.

The full mechanical drive consists of diesel engines coupled through clutches, gears, chains or cog belts direct to the drilling equipment. Considerable space is required around the rig floor for the equipment as it must be lined up with the hoist and rotary table. Sometimes this space is not available while in other cases the ground is swampy or covered with water such as found in many of the Venezuelan fields.

The diesel electric drive, on the other hand, can be mounted at a distance from the rig feeding power through cables to the electrical equipment on the rig floor. This drive is extremely adaptable when the well is under water as the diesel electric equipment can be placed on a barge.

In comparing load efficiencies of the two types of drive the actual conditions that must be met in drilling an oil well should be taken into consideration.

The over-all full load efficiency of the straight mechanical drive is between 90 and 97 percent, depending on the transmission system whereas the diesel electric drive will run between 82 and 86 percent. If the loads, speed and torque were constant without reverse rotation, the mechanical drive would be superior, but this condition does not exist.

The real characteristics encountered in drilling are varying loads, reversing loads, various values of torque and varying speeds. With this in mind the diesel electric drive is able to offer its real advantages as it meets these conditions in all respects. Figure 1 shows the real comparison in the two types of equipment. The curves in this figure show the speed of the driven shaft plotted in terms of percent of full load engine speed against the torque exerted on the driven shaft in terms of percent of full load engine torque. Four curves are plotted for the engine with 100, 95, 90 and 85 percent efficiency of transmission. The engine at all times is operating at 100 percent normal speed, having full load torque always available at the engine shaft. The driven

shaft speed and the torque exerted is varied by means of the transmission system through which the engine is driving.

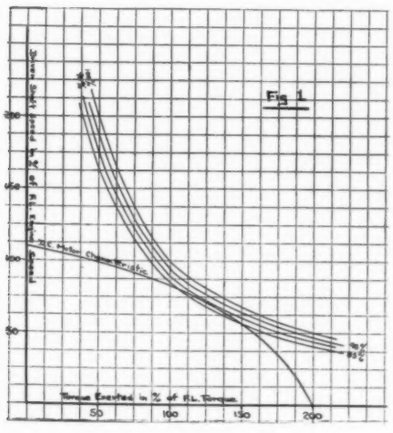
The motor speed characteristic shown is that which would be obtained from properly designed D.C. equipment being driven by the same engine. Let us take the hoisting cycle where the starting torque will probably be in the neighborhood of 200 percent full load torque, while the normal running torque after the load is in motion would be 100 percent of full load torque.

The mechanical drive must employ gear sets or some mechanical means to lower the driven speed in order to obtain the higher torque values. The clutch must be of sufficient capacity to accelerate this load at the increase torque value without stalling the engines. Referring to the curves of Fig. 1, it can readily be seen that after the hoisting operation has started the mechanical drive can only offer 50 percent of the driven speed, leaving the engines only half loaded. This is a serious disadvantage because the speed is fixed by the gear set and cannot be varied in proportion to the torque.

The D.C. electric drive can exert 200 percent full load torque at the start and as the load drops off the motor can be brought up to approximately 85 percent of normal full load speed. Here the engine would be operating at about full load and the pipe would be travelling twice the rate of speed that could be obtained by the straight mechanical drive.

Therefore the D.C. electric drive is more desirable because it can apply the greatest portion of the engine capacity to useful work regardless of speed or torque of the driven load. Even though the mechanical drive has a higher efficiency, it cannot keep the engine fully loaded throughout the work cycle because its speed is dependent on the starting torque and cannot be changed after the cycle has started.

Figure 1



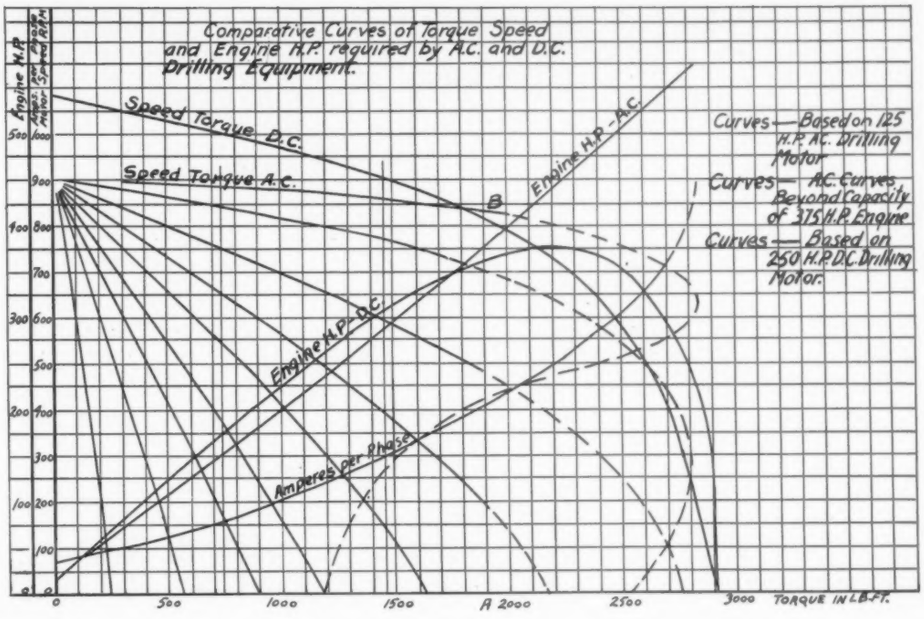

Comparative Curves of Torque Speed and Engine H.P. required by A.C. and D.C. Drilling Equipment.
Speed Torque D.C.
Speed Torque A.C.
Engine H.P. - A.C.
Engine H.P. - D.C.
Amperes per Phase
Curves — Based on 125 H.P. A.C. Drilling Motor
Curves — A.C. Curves Beyond Capacity of 315 H.P. Engine
Curves — Based on 250 H.P. D.C. Drilling Motor.
TORQUE IN LB-FT.

Figure 2

In the diesel electric drive, mechanical energy is converted to electrical energy which is transmitted to the source of utilization where it is transferred back to mechanical energy. The electrical circuit replaces the mechanical clutch and, due to the extreme flexibility of the electrical circuit, very fine control of the energy can be had.

The difference in initial cost between the two drives is the difference between the electrical equipment and the mechanical transmission.

This difference in cost sometimes is of sufficient importance to eliminate the possibility of using electric drive: it depends on the number of wells to be drilled, along with the advantages that the drive offers.

It now can safely be said that full load efficiencies may not be the most important factor in choosing the proper power transmission equipment. When ease of operation, convenience of speed control, and ratio of available engine horsepower to the horsepower applied to the drilling rig is considered, it is quite evident that electric power transmission is superior.

The question arises as to whether to use alternating current or direct current for the transmission. In order to make this decision, a careful study should be made of their advantages.

Advantages of the Alternating Current System

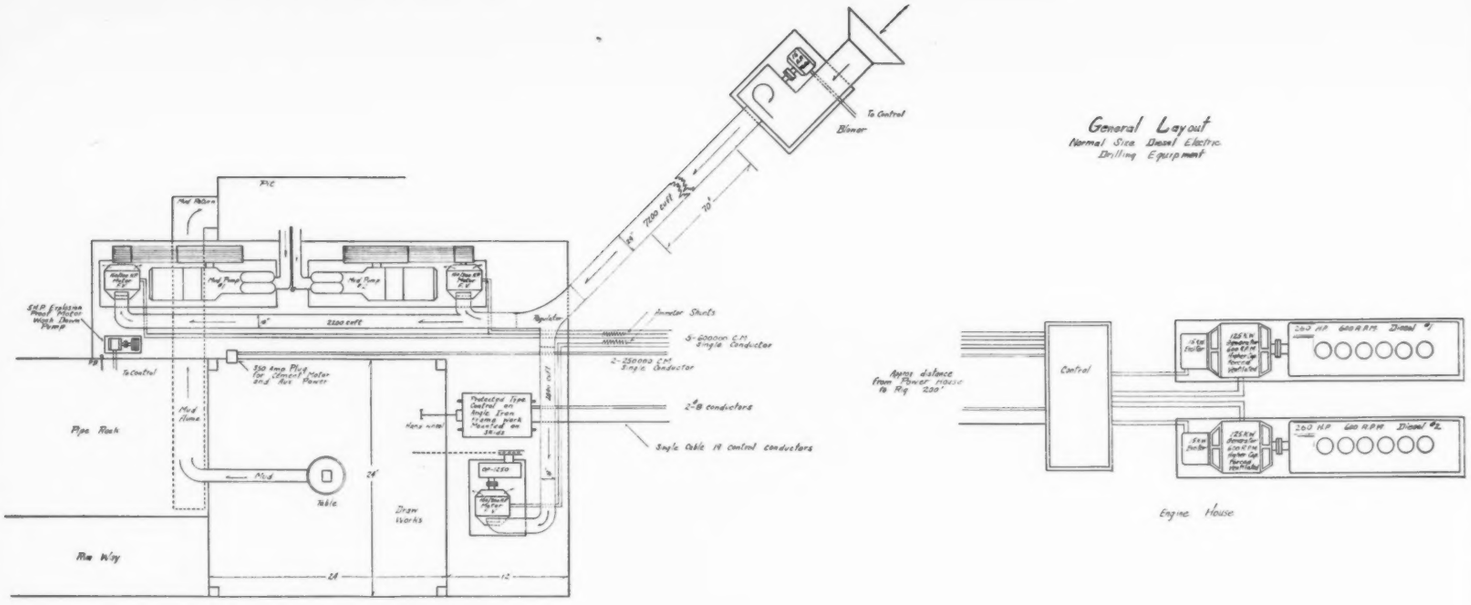
1. High load efficiency.
2. Low line losses.
3. Voltage can be stepped up by transformers for greater transmission distance and then stepped down at the rig to operating voltage.
4. Diesel generator units can be more readily converted to supply energy for pumping, or other oil field service if drilling operations should cease.
5. Drilling and mud pump motors with their control can be utilized more easily in other divisions.
6. Drilling equipment can be connected to transmission line if operating in electrified field.
7. Equipment easier to manufacture.
8. Additional engine generator sets can be added without trouble.

It must, however, be kept in mind that the alternating current circuit is a constant voltage system, and because of this the torque exerted by the motor governs the current flowing in the circuit and the engine output.

This system, therefore, replaces the mechanical clutch, giving much finer speed adjustment at all values of torque within the capacity of the engine. For instance, it is possible to accelerate a 100 percent load from zero to 100 percent speed. It does not, however, offer the drilling and hoisting characteristics that can be obtained from direct current equipment.

Advantages of the Direct Current System

1. Higher efficiencies at speeds less than full load speed which permits economical operation on light loads.
2. Higher starting torques obtainable.
3. Higher speeds at lower torques.
4. No overload relay required so that once the load has been picked up only engine failure can cause the equipment to drop the load which is a valuable point in hoisting.
5. The generator voltage characteristics can be designed so that it will be impossible to overload the engines regardless of the manner in which the control is handled, and yet a relatively high ratio of delivered horsepower to engine horsepower may be obtained through greater portion of the hoisting cycle.



6. Diesel engines may be operated at any desired speed up to normal speed which permits economical operation on light loads.

These characteristics favor the direct current system which represents the best method of drilling.

Fig. 2 shows graphically what may be obtained with either A.C. or D.C. equipment when operating with a total engine horsepower of 375 H.P. As stated previously, the torque capacity of the alternating current motor is limited by the engine horsepower. The line AB representing 1900 pounds feet torque is the limit of torque that may be applied to the load by the 125 H.P. standard drilling motor when drawing power from the engines totalling 375 H.P.

However, under the same conditions with the direct current equipment 2,900 pounds feet torque may be applied at starting.

The direct current system offers two methods of concentrating the power of two engine generator units together for the hoisting cycle. One is to parallel the two generators, while the other is to connect them in series.

The main advantage of the parallel system is that more than two generators can be concentrated on the system. This cannot be done with the series system because the voltage would be too high.

In the series system, however, it is impossible to obtain uneven load distribution between the generators because the same current flows through both generators regardless of the engine speeds. If the speeds are different the voltages of each generator will be different but the delivered voltage of the two units together will be the total of the two. In this way the voltage can be reduced by slowing down either unit. Voltage variation in the alternating current system will cause load shifts from one generator to the other. For this reason they must be protected by overload relays.

The series system in addition offers better emergency characteristics during the hoisting cycle. With this system if one engine generator set breaks down the operator can still get out of the hole in an easy manner. This is accomplished by using one engine generator which will deliver the same torque at half speed. In the parallel system when one engine generator set is down the hoisting motor can only deliver half the torque at full speed, unless the gear ratio is changed to lower the speed to half so that the torque doubles.

Since in the series system the current is only one half as great as that of the parallel system because of the doubling voltage, line losses from generators to drilling motor are less. Less copper can be used which makes the portable cables easier to handle and less expensive.

If all of these points are taken into consideration no trouble should be experienced in selecting the correct system to be used.

The characteristics of the series system makes it more adaptable in the major number of cases where the isolated well is to be drilled. For this reason the following comments are made on the important electric items of such a system.

The generators should be differentially compound with a three winding field consisting of a separately excited shunt field, a self-excited shunt field and a differential series field. The combination of fields should be such that the voltage will drop to zero when the current output is two times full load. The armature should be insulated for double voltage so that the generators may be operated in series from zero to twice generator voltage at full load. The commutator should be capable of commutating 100 percent overload current which is the maximum output of the generators.

The generators can be connected to the prime movers in one of two ways, direct on engine shaft or by means of cog belts.

If the direct drive is used the generators can be single bearing bracketed type machines with double shaft extension. The rear shaft extension will be for direct coupling to engine shaft while the front shaft extension will be for mounting exciter rotor. The direct drive offers the opportunity to mount the complete engine, generator and exciter on a common bedplate and skids.

The cog belt drive, however, offers the opportunity to reduce the initial cost somewhat as the generators can be designed for much higher speed, reducing the weight and size. In this case the generators should be three bearing units with direct connected exciters. In using this method the weight of any one single piece is kept to a minimum. They are not, however, as easy to line up at the point of drilling as the direct connected units.

A very popular scheme in the cog belt connection is to couple the two belt driven generators together and provide clutches on the engines so that on light loads only one engine need be run. This offers more economical operation.

The efficiency of these generators as a rule runs between 90 and 92 percent.

The exciters should be of sufficient capacity so that they can furnish excitation to all of the motors and generators, and power to energize the control circuits. In addition, they should furnish power for

the blower motor, wash down pump motor and lighting circuit.

The drilling can be accomplished by either one motor operating through a single drilling gear or two motors operating through a twin drilling gear. The two motor arrangement, of course, offers greater flexibility for with this arrangement the possibility of complete shut down is much less.

It is a good idea to have the mud pump motors and drilling motors identical so that complete interchangeability can be had. This also minimizes spare parts.

The motors should be shunt wound, separately excited, double rated, to permit operation with one generator or with two generators in series. When drilling with one generator at single voltage the horsepower and speed of the motors or motor would only be half of what they would be when the two generators are in series.

The variable voltage control equipment should consist of three parts; a splash-proof control cabinet for mounting at the generator, a protected type control unit for mounting on the rig, and handwheel and push button for mounting on draw-works post.

The control cabinet, which will be located near the generators in the generator house, should contain all of the air break unprotected contactors. This equipment is not protected against igniting explosive mixtures as it is intended to be located at a safe distance from the drilling rig. Upon the panel in the control cabinet will be mounted the rheostats, meters and switches. Complete operation for drilling and hoisting will be accomplished from the drilling rig by means of magnetically operated contactors located in the control cabinet and by protected type equipment located at the rig.

Control at the rig is sufficient for complete operation of the drilling rig after generators have been selected and connected at the generating point. Two air break protected type master switches mounted on one end and provided with sheave wheels control the fields of the two generators. Field resistors are mounted in the angle iron framework. During the drilling operation one generator supplies power to the drilling motor, the second to the mud pump motor while the master switches provide complete speed control. During the hoisting operation with the generators in series, the two master switches are operated simultaneously for control of the hoisting motor. The equipment is reconnected from the drilling set-up to the hoisting set-up by means of an arc break protected type sequence switch located on the angle iron framework. In case of emergency, or when the drilling load is light, the entire equipment may be operated from one generator. When this is done the speed control of the various motors is obtained by means of motor field rheostats also located on the angle iron framework.

The equipment located on the draw-works post control mechanism consists of two sheave wheels and two handwheels. The sheave wheels are provided for the operation of the master drums by means of telegraph cords. The two handwheels should be provided with a latch so that they may be located together to operate simultaneously or unlatched to operate independently.

A normal size 500 H.P. rig such as shown will not exceed 7 barrels of fuel oil and 2½ gallons of lubricating oil per 24 hours of operation.

▼

Economy in Direct Connected Diesel Power

Results from Actual Installations Prove the Superior Economy and Satisfactory Operation of Direct Diesel Drive for Rotary Drilling in Certain Cases.

As a result of low initial investment, and the fact that Diesels can be operated more economically than any other type of prime mover, the modern Diesel has established itself in oilfields for various drives, but most prominently for oil well drilling. Some recent installations illustrate situations in which Diesel power proves particularly advantageous.

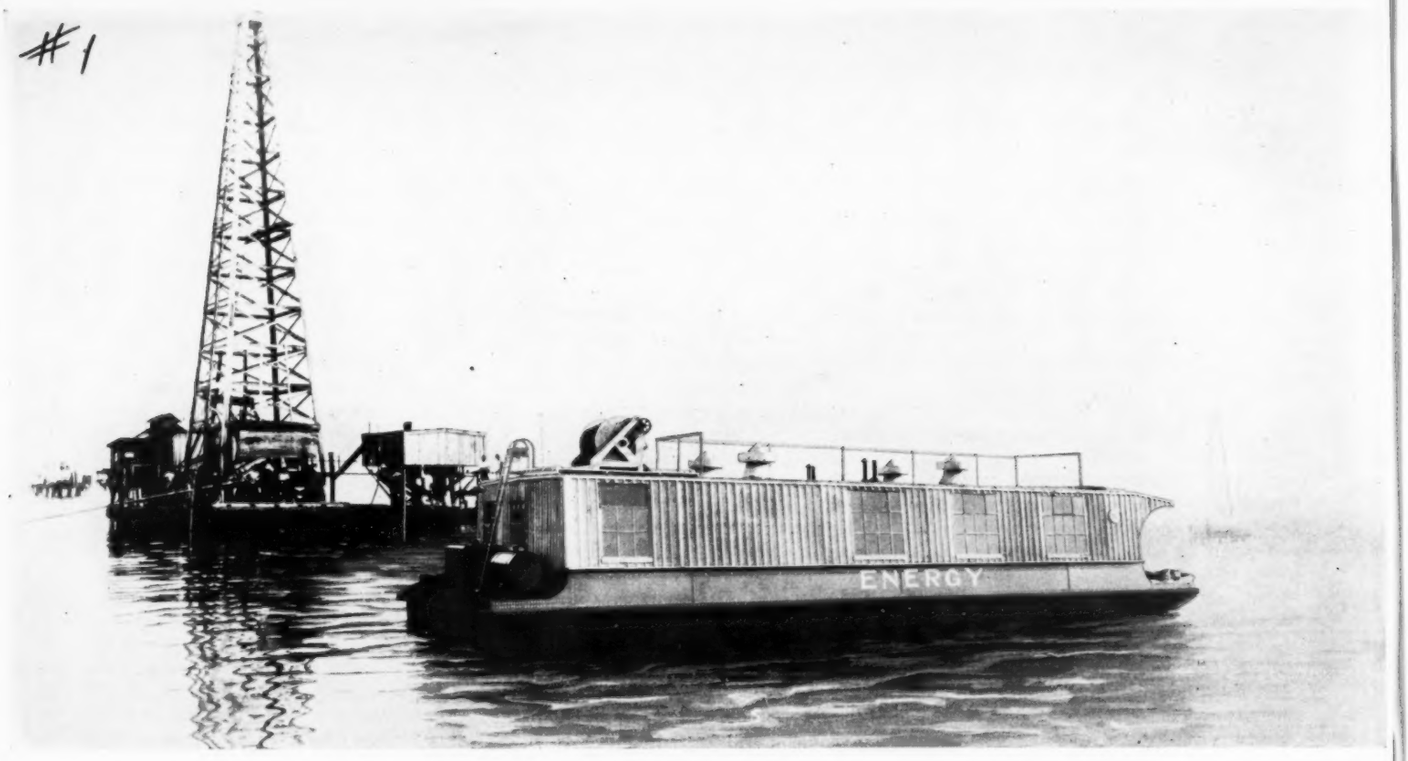
During 1930, The Texas Company designed a floating steel power house for this service. The power consisted of two 240 B.H.P. 6-Cylinder Cooper-Bessemer Diesels, direct connected to 2—175 K.W., 480-volt, alternating current Westinghouse Generators, with switchboard and controls installed in a scow bottom type barge, for use in the Louisiana bayous. The ENERGY as the barge was named has proven most profitable to the company. Adaptability of this outfit which can be floated from one location to another, at a considerable saving over moving any other type of power, without taking into consideration the low operating and maintenance costs, can be readily realized.

Another outstanding installation was made by the Associated Oil Company at Ventura, California, during 1935, consisting of one 400 B.H.P. 8-Cylinder direct reversible, marine type, Diesel engine.

Fixed and Operating Charges for Various Forms of Drilling Power

					Motor Generator Set	
	Steam	Diesel Electric	A.C. single Motor Drive	A.C. Hild Drive	Induction Motor	Synchronous Motor
Total cost of plant equipment	$17,605.00	$38,954.44	$16,932.00	$22,982.00	$24,457.04	$25,407.04
Total cost	19,700.00	47,006.85	19,027.00	25,132.00	29,807.04	30,882.04
Obsolescence—per year	2,145.92	4,502.04	1,497.84	1,779.16	1,847.75	1,891.93
Taxes and insurance—per year	591.00	1,410.21	570.81	743.96	894.21	926.46
Interest—per year	985.00	2,350.34	951.35	1,256.60	1,490.35	1,544.10
Maintenance—per year	1,475.90	3,734.37	1,373.20	1,580.00	2,304.63	4,870.19
Cost of pole line extension	.....	.....	2,500.00	2,500.00	2,500.00	2,500.00
Cost of fuel—per year	14,600.00	2,737.50	7,665.00	8,030.00	8,030.00	7,665.00
Cost of water—per year	14,600.00	73.00	.....	.....	.....	.....
Cost of lubricating oil—per year	273.75	146.00	91.25	91.25	91.25	91.25
Total charges per year	$34,671.35	$14,954.05	$14,848.20	$15,979.70	$17,158.65	$17,016.30
Total charges per day	94.99	40.97	40.68	43.78	47.01	46.62

Obsolescence was figured with interest at 5 percent. Taxes and insurance at 3 percent. Interest at 5 percent.



Diesel electric engines.

This prime mover was direct connected through a sprocket chain, to the draw works, without a reverse clutch, because the engine was a direct reversible type, which could be started, stopped, reversed and accelerated as required by the driller.

This being the very first attempt to direct drive a rotary draw works, without reverse clutch, it was decided to use steam for the mud pump service. In this manner a thorough study could be made of the Diesel as regards future possibilities. The hole was drilled to approximately 8,200 ft., using the old conventional type of draw works. The Diesel has now been removed from Lloyds No. 136 well as it is intended to reinstall it on a future new well, using a modern, six-speed, shaft driven, draw works with hydraulic engaged jaw clutches, which should improve operations to a point practically as flexible as any type of power available.

As to power costs of drilling, it is interesting to examine the accompanying figures compiled by one of California's major oil companies, for an outfit to drill to approximately 5,000 ft.

Associated Oil Company's installation required no Diesel engineer in attendance, as all operations were in the hands of drillers.

The total cost of this outfit completely installed was approximately $18,500, including the Diesel engine, auxiliary two-stage air compressor for starting, fuel oil pumps, lubricating oil pumps, water circulating pumps, Fluor semi-portable enclosed type cooling tower, tanks, etc.

Over a period of seven months the unit consumed an average of 2½ bbls. of fuel oil per day, at an average cost of $1.20 per bbl., and two oil changes were made in crankcase, requiring 50 gals. each change, with no make-up oil added between these changes. Thus we have a fuel oil cost of $3.00 per day, plus a conservative charge of two quarts of lubricating oil per 24 hours—total $3.25 per day fuel and lubricating oil.

Lloyds No. 136 drilled to 8,200 ft. by direct Diesel drive without a reverse clutch and using steam for mud pump service.

Water at Ventura, California is rather expensive, in addition to containing considerable alkali which is always detrimental to boilers. Most companies use water softeners in an attempt to reduce maintenance.

Two different California companies submit figures of $3,000 per month total cost, including fixed charges, for a bank of five boilers in service. This includes labor, also fuel, water, water softener, flue repairs, insurance, etc. On a complete Diesel equipped rig such as the Associated Oil Company's equipment, assuming Diesel direct drive to mud pumps, in addition to direct drive to draw works, it is estimated there would be a savings of approximately $2,000 per month over the steam equipped rig.

Another interesting Diesel installation was made by the Rowan Drilling Company late last year. This consisted of two Cooper-Bessemer Type FP 6-cylinder 250 H.P. at 525 r.p.m. vertical full Diesel engines, "V" belt driving generators. This outfit has already completed one well and has been moved to another location in Pearsall, Texas, and is now in service. This company also installed one 6-cylinder 190 H.P. at 600 r.p.m. vertical full Diesel engine for cable tool drilling.

The two FP units use approximately 275 gals. of fuel oil per day.

Precision in Feed Control

"—with an Engine Throttle Valve, a Hydraulic Feed Control Discharge Valve and The Necessary Indicating Gauges, a Driller Has Positive Control."

By J. E. Brantly

WITHIN the function of the boring of a hole into any substance there are four primary factors involved, which, for maximum efficiency of operation, must be maintained at their highest proper values consistent with a balanced relation between them. These factors are the bit or boring tool, rotation of this tool, weight or pressure applied to the cutting edges, and the removal of the cuttings from the path of the cutting tool as they are formed. Each of these four involves a variety of means, methods, and operations which go to make up the primary factor and which must be adjusted to the conditions encountered for a properly balanced and efficient operation.

In its broad fundamental principles the boring of a hole into the crustal formations of the earth in the search for oil or gas is no different from the drilling of a piece of metal, wood, or stone. The same factors are involved and the same details of operation must be observed.

This article deals with means and methods for maintaining a uniform weight on the cutting tool during the drilling of a given formation. The regulation of this weight requires a means for imparting a uniform feed of the tool into the material being drilled. The resulting uniformity of pressure of the bit on the surface being cut is essential for maximum efficiency in any boring operation. If this pressure is not continuously applied in correct degree there will necessarily be periods of excessive weight and of insufficient weights. The excessive weight will unduly wear or break the cutting tool or its edges and, if the excess applied is sufficient, will have a tendency to bend the drilling shaft above the bit with resulting hole deviating from the desired direction. Excessive weight will likewise unduly burden the operating equipment above the cutting tool. During the periods when the weight is insufficient the tool cannot penetrate the formation to the depth necessary for the normal cut with the consequence of a subnormal rate of penetration. Wear of the cutting edge is practically as much or, in some cases, more than when proper pressure is used.

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J. E. Brantly

In relation to the work done the rotating shaft, to which the bit is attached, used for boring holes into the earth is the weakest of all tools employed for similar purposes. Therefore, the greatest delicacy of operation is essential if maximum efficiency is to be obtained and straight holes drilled. As the search for oil reaches into deeper and deeper horizons and the problems increase in complication, the need for greater nicety in the handling of the tools and equipment becomes even more apparent. It is also evident that in the more difficult shallow wells, particularly where the formations are hard or steeply inclined, this same delicacy is a requisite for even fair efficiency.

In maintaining uniform weight on the cutting tool, mechanical means, other than the ordinary hoisting drum brake, are essential for imparting a uniform rate of feed of the bit into any stratum or series of strata of uniform hardness or drillability. The following paragraphs will be devoted to very brief descriptions of the various methods presently in use for the accomplishment of this regular and smooth feed.

In order to maintain a uniform weight on a cutting tool in a given formation a means for imparting a regular and uniform rate of feed to the bit is necessary. Machines designed for this purpose which are being called "Feed Controls" are of two general classes; firstly, those that are actuated by the weight of the drill pipe alone; and secondly, those that require power from an outside source to effect their particular method of feeding the drill pipe into the hole. These two classes are built to control the rate of feed and thereby to maintain a uniform weight on the bit. Still another class is designed to control the rate of feed into the hole by maintaining a given torque load on the drill pipe which may or may not be a function of the weight on the bit, or the rate of penetration.

Of the first mentioned class there are two types, namely, those that carry all or a substantial part of the weight of the drill pipe on the fluid in one or two vertical hydraulic cylinders and which are a part of or intimately associated with the rotating means; and the feed control that consists of a single or multi-cylinder reciprocating hydraulic engine or pump arranged to support the weight of the drill pipe through control of the proper shaft or shafts on the draw-works. These last mentioned feed controls may or may not be designed to retrieve the drill pipe

though the vertical cylinder types always are. In the class of feed controls using an outside source of power there are likewise two types, those using steam or air as the power medium and those using electricity. In the following paragraphs these several classes and types of controls will be very briefly discussed.

In the oil well drilling, core bits set with black diamonds or carbons have been in use for many years. In order that these delicate tools could be used economically and efficiently it was early recognized that the maintenance of a uniform weight on the cutting tool was essential, and to maintain this uniform weight a regular and smooth feed was found to be necessary. For these closely dependent purposes the diamond drillers developed a screw type feed for small hand machines and a hydraulic feed for the larger units. The first development, and one that is still in use, is the single hydraulic cylinder type having a hollow shaft through which the drill pipe or drill rods are passed and positively fastened thereto. Satisfactory means for rotating the drill rods or drill pipe are then supplied. This hydraulic cylinder, together with its piston, are set in a vertical position centered over the hole to be drilled or on the extension of its axis, where the boring is to be at some angle from the vertical. With ordinary drilling under way the piston is elevated to the top of the cylinder by pumping water or other satisfactory fluid into the cylinder beneath the piston. All valves leading from the lower side of the cylinder are closed and the drill pipe made fast in some satisfactory manner to the hollow piston rod, the drill rod or pipe is then rotated, the circulating pump started, and drilling proceeds. As the bit cuts headway, the discharge valve from the cylinder beneath the piston is opened to that extent which will permit the drill pipe to feed off into the hole at that rate which will maintain a steady and even pressure on the cutting tool. Obviously, for formations of changing drillability varying weights on the cutting tool and consequent varying rates of feed are necessary for maximum efficiency. The total weight may be determined by the use of an ordinary hydraulic pressure gauge connected with the fluid in compression below the piston. With the bit off bottom, the weight of the drill rods in pounds of pressure is shown, and the weight on bottom may then be controlled as desired by the manipulation, manually or otherwise, of the discharge valve leading from the fluid beneath the piston, which regulates the rate of descent of the piston and pipe. Ordinarily the entire weight of the drill pipe is supported by the hydraulic cylinder, though occasionally a part of the load is carried on the hoisting line. In this case control from the pressure gauge is somewhat more difficult, however diamond drillers are generally of that experience which permits them to drill with reasonable efficiency without reference to a weight indicator and at least a uniform or smooth feed may be maintained. Machines of this type have been and are being used very successfully in drilling holes varying in depth from a few hundred feet down to ten thousand feet or more in prospecting for mineral deposits, drilling for oil and gas, and for other purposes. These single cylinders may either be above the derrick floor, as is the case in the usual diamond drill, or placed in the rotary table, as is customary in machines designed for the heavier oil field duty.

Another type hydraulic drilling feed device that carries the entire weight of the drill pipe has two hydraulic cylinders with the drill pipe supported in a satisfactory manner on a beam, the ends of which are supported by the pistons of the hydraulic cylinders. These machines are identical or at least closely similar in action and control to those of the single cylinder type, and as machines capable of maintaining a perfectly even weight of the bit through means of a uniform rate of feed, they are, together with the single cylinder type, preeminently better than any others in use. When using such costly cutting tools as a core bit set with diamonds a delicate feed of this type is absolutely essential but it seems doubtful, however, that such nicety is required in ordinary oil field practice.

These machines vary from twenty inches to ten feet in piston stroke or depth of penetration before a new "hitch" is taken. Properly designed, the several types are equally capable of imparting the desired feed, therefore the most satisfactory machine for a given job depends upon its first cost, the cost of erection, and the cost of the time lost in making the change in the hold on the drill pipe from the bottom of the piston stroke to the top of the piston stroke. In light duty operation, machines of the old diamond drill type seem to be more satisfactory. In heavy duty oil field work, however, machines of this design can offer no competition to those that utilize rotary tables of the hydraulic or ordinary design.

In pressure control work, hydraulic machines of these vertical cylinder types are very useful, since in addition to the ease with which they handle flush joint pipe, hydraulic pressure can be applied above the piston and the bit consequently held on bottom when there is insufficient weight in the drill string to do so.

In order to avoid the very considerable lost time in making the chuck changes on the short stroke, direct acting, hydraulic feed, and to reduce the first cost but still retain the advantages of the uniform feed, a new type hydraulic control has been developed and recently put into service. This machine consists of a multi-cylinder double acting hydraulic engine or pump which is attached, through an ordinary gear box speed increaser and the necessary chains and sprockets, to the line shaft of the draw works and thence to the drum shaft, or, directly to the drum shaft. Its principle of operation is best described in relating its manner of use which is somewhat as follows:

When the bit is within a few inches of bottom and ready to resume drilling, the clutch or clutches, which connect the hydraulic cylinders to the hoisting drum through the single chain from the drum shaft to the gear box or the two chains from the drum shaft to the line shaft and thence to the gear box, are engaged, the brake lever thrown back and the brake band entirely relieved of contact with the brake rim. Thus the feed control acts entirely independently of the brake. With the discharge valve from the multi-cylinder pump closed the entire weight of the drill pipe is supported, through the usual equipment and that just mentioned, by the fluid contained in the cylinders of the pump. The driller then opens the valve on the discharge line from the pumps and the pistons are caused to reciprocate by the power supplied by the dead weight of the drill pipe hanging from the drilling line. This imparts a torque to the drum shaft equivalent to the dead weight of the drill pipe divided by the number of lines up. This torque is transmitted through the sprockets and chains to the gear box and thence to the crank shaft of the multi-cylinder pump, and thus, the mass of the drill pipe is the source of power or the prime mover used to operate the pumps. This mass may be compared to a motor for purposes of explanation. With the discharge line from the pump fully open, and the motor receiving its full energy from the power lines, it will run at its maximum speed allowed under the conditions. As the size of the orifice in the pump discharge is decreased or as a valve on this line is closed a smaller quantity of fluid is discharged and in consequence a back pressure will be built up and the speed of the motor decreased. As the orifice of the control valve on the discharge line is further decreased until entirely closed, the motor will slow down and finally stall. The movements of the drill pipe or its downward feed into the hole is controlled in the same manner as is the speed of the motor, that is to say, with the valve in the discharge line wide open, the drill pipe will feed downward at

its maximum allowed rate which will be decreased as the size of the orifice is decreased. The downward movement of the pipe will stop entirely with the discharge valve fully closed. The units presently in service are capable of permitting a feed varying from zero to 90 ft. per hour. These rate limits seem to be entirely adequate to meet any conditions found in ordinary drilling practices. This type of machine is continuous in its operation and permits constant, regular feed for the full length of any kelly or drill stem.

Any hydraulic feed control, whether of the direct supporting type or the indirect as just described, may be made to function automatically, controlled either by the weight on the bit or by the torque to which the drill pipe is being subjected. It is the opinion of the writer that automatic control of the rate of feed either from the weight on the bit or the torque in the drill pipe is less desirable than manual control. With a throttle on the drilling engine and the steam pressure gauge on the drilling engine manifold, the gauge showing an indirect indication of the torque, the rotating speed may be regulated to that which is desired up to the maximum permitted steam manifold pressure, likewise, with a valve on the discharge line from any hydraulic feed control and the weight indicator of satisfactory type the valve may be so manipulated that a uniform weight on the bit may be maintained by means of a regular rate of feed in a formation of uniform drillability. Thus, with an engine throttle valve, a hydraulic feed control discharge valve and the necessary indicating gauges a driller has positive control over these drilling factors of rotating speed and weight within the limits desired.

Any automatic type of feed must base its control either on weight on the bit or torque in the drill pipe. Of these two types those based on weight appear to be more desirable since torque is not necessarily a function of the rate of drilling. However, manual control of the drilling engine throttle valve and the hydraulic feed control discharge valve, which thereby permit the control of speed of rotation and torque and the rate of feed and weight on the bit, seems to be, within present knowledge of drilling operations safer and more efficient than any automatic control which has yet been devised.

The next type of feed control for consideration is that which requires an outside source of power in order to effect its control. There is one type which may be applied to the hoisting drum on which the live end of the line is spooled, and there are others built to work on the standby unit drum which carries the dead end of the line. An immediate disadvantage of this last mentioned is that a standby hoist readily capable of retrieving the drill pipe at a reasonable rate is necessary. Both types may be fully controlled manually or may be designed for automatic control over rate of feed, governed either by torque or weight or both. It would seem, however, that full manual control is to be desired. These feed controls may be and are built to retrieve the pipe slightly if the torque exceeds a predetermined limit in a torque control machine or if the weight exceeds a certain maximum in a weight controlled unit. It seems to be obvious that if the drilling is not forced or is held at the proper maximum then the retrieving of the pipe, which is lost time, will not be necessary.

Probably the simplest of these feed control machines, which require an outside source of power, is one that is attached through proper chains, sprockets and clutches, to the working drum shaft. The machine consists of a speed increasing gear box of adequate design having each end of the high speed shaft extending a satisfactory distance from the gear box. To one end of this shaft is attached a positive brake of some kind which may be electrical, hydraulic, or friction. This brake, having variable tension, may be set so that it will support the weight of the drill pipe plus a satisfactory excess. To the other end of the high speed shaft there is attached a variable speed electric motor or other suitable prime mover. When drilling is in progress this prime mover is operated with that amount of power sufficient to overcome the resistance of the brake on the other end of the high speed shaft and at that rate of speed necessary to maintain the rate of feed of the drill pipe that will keep the desired weight on the bit. This unit with proper brake design will retrieve the drill pipe within the speed limits permitted by the very small prime mover.

Still another type feed control, of which there are several in use, involves a hoisting drum, to which the dead end of the line is attached, a gear box containing a worm gear and pinions, and a reversible steam engine or electric motor. A chain connects the drum, through its sprockets, to a companion sprocket or to the gear box. The design of the worm gear and its pinion are such that the gear cannot drive the pinion because of the screw pitch, therefore, the drum is held stationary against the pull of the dead line, even though no power is applied to the holding pinion through the prime mover.

When it is desired to feed the drill pipe into the hole, an automatic device supplies the prime mover with power sufficient to cause it to rotate the worm pinion in that direction, which, through the gears, sprockets, and chain will play the line from the drum, thus permitting the downward movement of the bit. Should the drilling factors involved in the automatic control become such as to make it desirable to raise the drill pipe necessary power is applied to the engine or motor in the reverse direction and the drill pipe elevated to the extent regulated by the control. When the full length of the kelly has been drilled, the unit is used to pick up the drill pipe in order that an additional joint of pipe may be placed in the drilling shaft, or a connection made.

The automatic control of the prime mover or of the unit may be based either on torque on the drill pipe or weight on the bit. Manual control by the driller, from visual weight and torque indicators, would seem to be entirely feasible and probably more desirable. This type feed control seems to function quite satisfactorily, though the automatic control device is not, as yet, entirely reliable.

The differential gear drilling control requires the use of two reversible prime movers, generally electric motors, connected to opposite shafts of a differential gear. The balanced relation between the motor, acting through the differential, is such that when the torque required to maintain a given rotating speed on the drill pipe exceeds a predetermined limit, the feed off into the hole is retarded or the bit is actually lifted off bottom until the rotation torque and speed have again reached their normal and the feed off is resumed. A decrease in torque or increase of rotating speed causes the machine to feed the pipe into the hole at a faster rate. These controls are usually electrically powered and operated though steam engines as prime movers are likewise employed.

▼

B.O.D. Rent

THE sum of £175,000 in gold was paid over to the Iraq Government by the British Oil Development Company as dead rent under the terms of the Mosul oilfields concession. This amount was handed to a representative of the Iraq Government at its Embassy in London during the last week-end of March on the return from Baghdad of two Americans, Mr. Hansell and Mr. Collins, who had carried out a tour of inspection of the B.O.D. oilfields in the middle of March.

Salvaging 30,000,000,000 Bbl. of Crude

Relative Efficiencies of Secondary Recovery Methods, One Or the Other of Which Will Probably Eventually Find Application in Every Oil Field.

By Lester C. Uren

Professor of Petroleum Engineering
University of California

KNOWLEDGE of the limited character of the known reserves of petroleum, when measured in terms of the current and prospective demand for petroleum products, has led many oil producers to interest themselves in recovery methods that seem to offer the means of securing a larger percentage of the original oil content of a pool than is possible by ordinary methods of field exploitation. A large part of our original endowment of petroleum in oil fields thus far discovered has been left behind in the reservoir rocks, unrecoverable by methods commonly used in oil-field production practice. This residue of petroleum, unrecoverable by ordinary methods of field exploitation, is possibly of greater magnitude than the undiscovered reserve represented by fields that have not as yet been penetrated by the drill. It is therefore of interest as the reserve from which a large part of our future supply of oil products must be won.

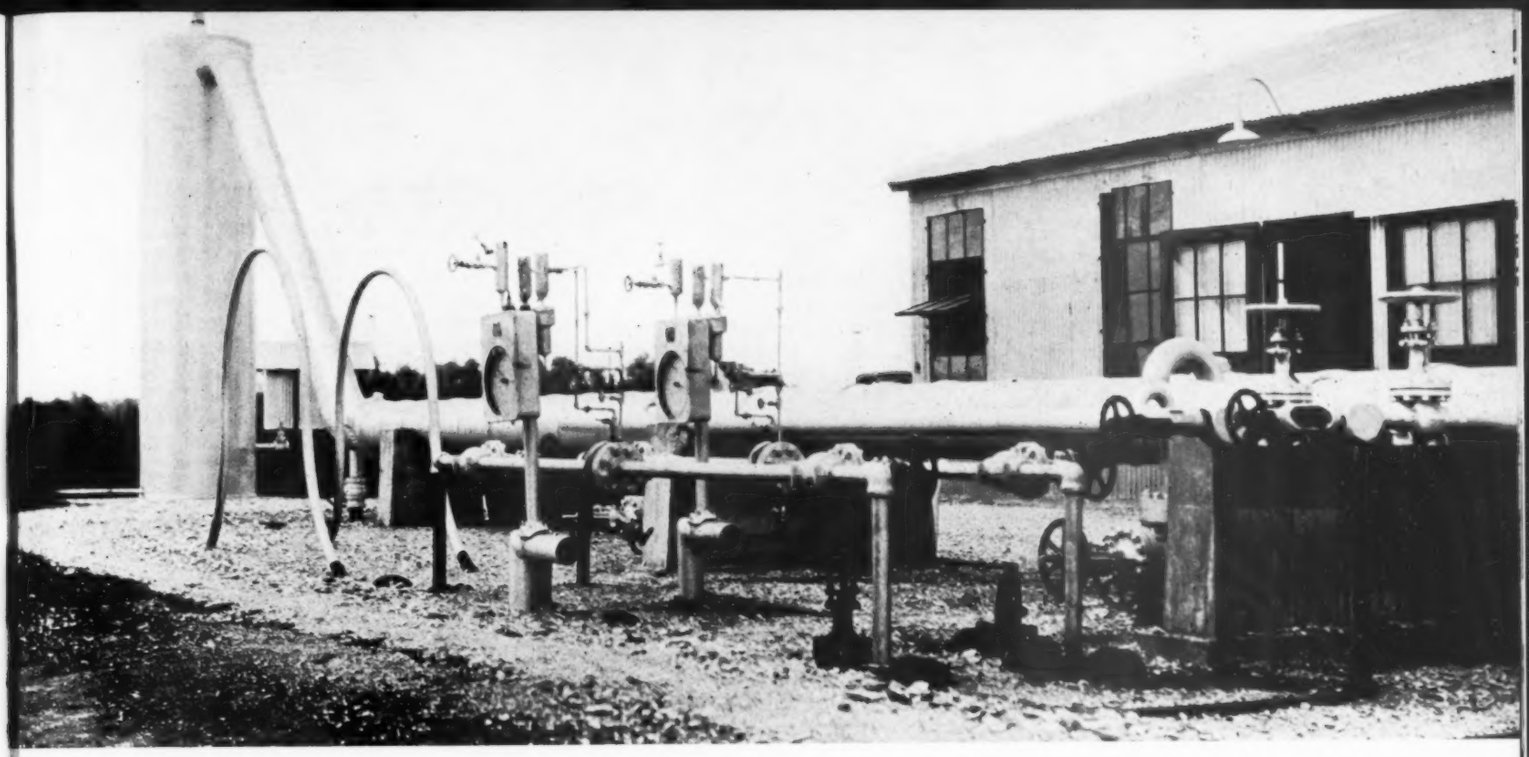
The more efficient methods of recovery by means of which the residual oil in our older fields may be partially recovered are not new; but the growing realization that one or another of them will probably eventually find application in every oil field, and that continuance of profitable operation in many hundreds of our older pools is dependent upon them, has led operators to look upon these methods with considerably renewed interest. The secondary recovery methods include systems of exploitation involving (1) injection of gas under pressure into the partially depleted reservoir rock; (2) flooding with water; and (3) drainage through mine openings. Each of these methods has already found application on a scale sufficiently large to demonstrate its economic feasibility. Each has been extensively studied under laboratory conditions and in field-scale projects. This article presents a brief review of factors that must be considered in making a choice of one or another of the several methods under given field conditions, and discusses their relative advantages, disadvantages and efficiencies.

PERCENTAGE ULTIMATE RECOVERY BY PRIMARY METHODS. The percentage of the original oil content of an oil reservoir rock secured in ordinary methods of field exploitation by flowing and pumping through wells, has been the subject of a great deal of discussion among petroleum technologists, and there appears to be a wide diversity of opinion as to the recovery efficiency attained. Estimates of different authorities range from 10 to 80 percent or more. The higher recoveries are assumed for fields in which oil is displaced from the pore spaces of very permeable reservoir rock by edge-water which encroaches as rapidly as the oil is withdrawn. When gas expansion is the expulsive force immediately operative, a smaller percentage yield usually results. When expressed opinions are based upon laboratory research or careful analysis of field data, estimates seldom exceed 30 percent and are often less than 20 percent. It is generally agreed that the percentage gas recovery will be materially greater than that of oil, the only factor limiting complete drainage of the gas being the minimum residual or equilibrium field pressure. The percentage recovery by gas expulsion increases directly with the initial field pressure. Recoveries as high as 40 percent have been secured in laboratory apparatus from highly permeable, gas-saturated oil in unconsolidated sands with initial saturation pressures of 800 pounds per sq. in. In the field, where drainage is impeded by irregularity in sand permeability and by the greater distances over which flow must occur, the percentage yield is doubtless much less.

Actual recoveries in producing oil fields are reported to be as low as 15 or 20 percent by many authorities. Actual underground sampling and testing of the reservoir sands in the Pechelbronn oil mines, Alsace, indicated that recoveries by earlier exploitation to economic exhaustion through wells was less than 17 percent. Recovery estimates for the Bradford field of Pennsylvania, by ordinary methods of flowing and pumping, have been placed by Mr. David White of the U. S. Geological Survey as low as 12½ percent. In diamond drilling between wells in certain oil fields of northern Pennsylvania that have been producing for more than 60 years, part of the time with the wells under vacuum, the writer found that much of the oil-bearing formation cored still contained upwards of 90 percent of its original oil. Even the more permeable strata were found to be more than 60 percent saturated. In a statement before the Federal Oil Conservation Board, Mr. J. O. Lewis, who has had an extensive experience in application of secondary recovery systems, expressed the opinion that in the average American oil field we produce only one-seventh of the original oil content by ordinary methods of pumping and flowing.

Those who believe that recoveries of the order of 50 to 80 percent of the oil present in a reservoir rock may be secured in ordinary field operations, generally assume that encroaching edge-water will displace much of the oil left behind by gas expansion and gravity drainage. In some cases, where cores have been taken of a sand stratum behind an advancing edge-water front, the pores of the sand have been found practically free of residual oil. However, it is questionable whether in such cases the oil may not have been in part displaced from the sand during the process of cutting the core. Even though one might concede that the more permeable drainage channels are washed fairly free of advancing edge-water, there is good evidence for the belief that the water advances quite irregularly through different portions of the reservoir rock. It therefore seems likely that only rarely under field conditions, even when expulsion of the oil is aided by advancing edge-water, does the average percentage recovery exceed 50 percent.

NECESSITY FOR PRELIMINARY FIELD STUDIES BEFORE ATTEMPTING TO APPLY SECONDARY RECOVERY METHODS. Before selection of the recovery method to be employed and prior to attempting its application, it is desirable that a thorough engineering study be made of the field conditions presented which may influence its ultimate success. In this study, all available well data should be assembled,



This elaborate-looking set-up is used for trapping and metering gas at a gas compressor plant in Sugarland Field, Texas.

together with such data as may be available relative to water conditions, volume of gas and sand produced with the oil, thickness, lithologic character and uniformity of texture of the reservoir rock, initial production and production decline data.

The most important consideration is that of estimating the volume of residual oil left in the reservoir rock by the earlier exploitation and the distribution of the residual oil, both laterally and vertically within the productive formation. The more permeable areas and component strata within the reservoir rock and the areas near the wells are more thoroughly drained during primary exploitation. We may therefore expect to find a larger percentage of the original oil in the less permeable strata and in less favorably situated areas, remote from the wells previously operated.

The thickness and character of the reservoir rock throughout the area to be drained can best be determined by drilling new wells between the older wells, coring the entire thickness of the producing formation. The diamond drill is well adapted to this type of work, producing a complete core that is more truly representative of the reservoir rock than any other type of formation sample. In well indurated rocks such a core will show every detail of bedding and will even indicate, in a qualitative way, the character of the fluids present in each. Special sampling devices have also been developed for securing well samples from wells previously drilled, but they are applicable only where the walls are not cased. Representative formation samples thus obtained are subjected to laboratory tests to determine porosity, grain size distribution, permeability and oil saturation. As a result of careful sampling and analysis of this character, it is possible to construct profiles showing variation of these factors throughout the entire thickness of the producing formation. Such profiles indicate the component strata of the reservoir rock that contain the most oil, and are suggestive of ways of applying secondary recovery methods.

Still another method of determining the relative permeabilities of different strata penetrated by a well, is that of applying a uniformly high gas-pressure to each stratum and noting the rate at which gas enters the formation. This may conveniently be accomplished by lowering into the well a column of tubing with a short section of perforated pipe on the lower end, and equipped with two adjustable packers, one above and one below the perforated section. The lower end of the column of tubing is closed. By setting packers against the wall of the well and forcing compressed gas down through the tubing, the gas has access to the formation only between the packers. The volume of gas entering the formation under constant pressure, determined by metering, becomes a measure of the permeability of the particular section under test. By starting at the bottom of the well and testing at short intervals up the hole in this way, we may determine the relative permeabilities of all producing strata.

We may also form some opinion concerning the characteristics of the reservoir rock penetrated by each well, by inspection of the production records of the individual wells. Those developing the larger initial productions at a given time and under comparable reservoir pressures, are wells that are surrounded by more permeable reservoir rocks. For wells having comparable structural positions, those producing with lower-than-normal initial gas-oil ratios are probably producing from more permeable reservoir rocks. The development program followed in spacing and timing the drilling of wells may also afford an indication of the recovery efficiency achieved by primary exploitation. Widely spaced wells leave much of the oil unrecovered between the old locations. Delay in drilling wells, in terms of the rate of surrounding development (thus permitting undue loss of reservoir pressure before all wells are drilled), results in a low percentage primary recovery, and hence properties that have been handled in this way are especially attractive for secondary exploitation. Wells that are provided with or naturally develop large cavities about them within the reservoir rock secure more efficient drainage than do wells of normal diameter, and hence leave a smaller percentage of the original oil content of the reservoir rock available for secondary exploitation.

Applicability and Efficiency of the Gas-injection Methods

THE gas-injection methods include three essentially different systems of exploitation which are called: (1) "pressure maintenance;" (2) "pressure restora-

A gas injection well in the Dominguez Field, California. The "pressure-maintenance" system is being used here.

tion;" and (3) "gas driving." Each has its special sphere of application; each is most efficiently applied under particular circumstances.

1. PRESSURE MAINTENANCE. This system of exploitation involves reinjecting all gas trapped from the oil back into the formations from which it came. By inaugurating this procedure early in the life of an oil field, we may maintain the formation pressure at a relatively high value, or at any rate, we may prevent a rapid decline in reservoir pressure which would otherwise occur. In field application of the method, the gas-injection wells are preferably situated at or near the structural crest, while the producing wells are located well down on the flanks of the structure, away from the crestal area. By continued application of the process, a large body of gas accumulates in the crest of the structure, to be produced and marketed after the reservoir rock has yielded all of its drainable oil.

An important advantage of this system of field exploitation is found in the ability to maintain materially higher average formation pressures than would otherwise be possible. With field pressures substantially maintained, the original gas remains largely in solution in the oil except in the immediate vicinity of the producing wells, and the viscosity and surface tension of the oil are maintained at low values. Energy contributed by recompression of the gas, added to that originally provided by nature, assures a larger ultimate recovery than would be possible by natural recovery methods. High reservoir pressures assure a higher average daily rate of production than would normally be realized, and a large part, perhaps the entire production, could be secured by flow methods, thus assuring low unit production costs.

In fields where an original gas cap exists and the reservoir rock at the crest of the structure yields gas with no oil, injection of recompressed gas through crestal wells will prevent oil from rising into the upper part of the structure, and becoming permanently lost by adhesion on dry mineral surfaces. Maintenance of uniformly high reservoir pressures also prevents invasion of the oil producing areas by edge-waters.

The pressure maintenance method is possible of application only during the early period of exploitation of an oil field, before formation pressures have been seriously depleted. The method is only applicable to pools operated as units, or at any rate, tracts must be sufficiently large to prevent movement of oil and gas to neighboring tracts operated under lower pressure. Well defined structures having steep dips are better adapted to maintenance of gas caps without by-passing of gas from the crestal area to the recovery wells. By-passing is also more likely to occur when some stratum or strata are much more permeable than others in the formation comprising the reservoir rock.

There are several instances in which the pressure maintenance method has been successfully applied under field conditions. Notable among these is that of the Sugarland field in southern Texas, where the Humble Oil and Refining Company has for several years followed the practice of compressing all gas trapped from the oil and reinjecting it into the reservoir rock through wells at the crest of the structure. The original field pressure was between 1,400 and 1,500 lb. per sq. in. and at no time during the first seven years of exploitation has the formation pressure been permitted to fall below 1,200 lb., though upwards of 23,000,000 bbl. of oil were produced during this time. Upwards of 85 percent of the gas produced is returned to the reservoir rock, net gas-oil ratios—representing the difference between the volume of gas produced and that returned to the wells—averaging only about 35 cu. ft. per bbl. All oil has been lifted by flow methods. It has been estimated that upwards of 35 percent of the gross original content of the Sugarland pool will be produced by the pressure-maintenance method, or about twice as much as would have been secured by ordinary methods of flowing and pumping. The cost of recompressing and injecting the gas has been only about 2-cents per barrel of oil produced.

2. PRESSURE RESTORATION. This method is applied to partially drained reservoir rocks in which the field pressure has been largely depleted and in which the production rate has declined to low levels. Gas is forced into the productive formation at the locations where conditions seem favorable, while all other wells are shut in until pressure is restored throughout the entire reservoir. The voids in the reservoir rock are thus filled with high-pressure gas, some of which is taken into solution in the oil. Several months, or perhaps a year or more will be necessary to build up the desired pressure, but when this pressure is reached, gas injection is stopped and all of the wells are permitted to produce under the influence of artificially rejuvenated field pressure. When the gas pressure has become exhausted by continued production, the entire process may be repeated if the probable value of a third crop of oil justifies the cost.

In an experiment conducted in a large sand-filled pressure-drainage tank in the petroleum engineering laboratories of the University of California, ten successive pressure restorations to a maximum of 50 lb. per sq. in. were made and the pressure exhausted eleven times, additional oil being secured with each pressure restoration from miniature wells penetrating the sand body. The first release of pressure, starting with the pore spaces of the sand saturated with oil, yielded 20.3 percent of the oil content of the sand; the second yielded an additional 6.7 percent; the third, 6.5 percent; the fourth 4.5 percent, and so on, each successive pressure restoration resulting in a smaller yield than the previous one. The cumulative total recovery, obtained by eleven exhaustions of pressure, was about 48 percent of the saturated oil content of the sand. The results of this experiment can scarcely be accepted as comparable with what might be expected under field condi-

tions, but it is interesting to note that material contributions were secured by the second and third restorations of pressure.

An experimental project on a field scale, to determine the efficacy of the pressure restoration method, was conducted by the Humble Oil and Refining Company in the Olney pool, a small field in north-central Texas. Here 21 wells had been drilled about 300 ft. apart into a small dome, the productive area being only about 80 acres. After producing some 350,000 bbl. of oil by ordinary methods, including use of vacuum, the wells had about reached their lower limit of profitable production, averaging only two to three bbl. per well per day. During a period of nearly two years, about 109,000,000 cu. ft. of gas was injected into the partially drained reservoir rack through some of the wells, building up pressures about the injection wells to upwards of 400 lb. per sq. in. After standing for a time, pressures throughout the field became better equalized, the average field pressure being estimated at about 350 lb. per sq. in. During three subsequent years when the wells were again permitted to produce, the field yielded an additional 122,000 bbl. of oil, or about 35 percent of the primary production and the field pressure was still above 200 lb. per sq. in. During production after repressuring, all surplus gas above what was needed for fuel purposes was reinjected at certain wells near the crest of the structure reserved for this purpose. This experiment was really one combining the principles of repressuring and pressure-maintenance.

The pressure restoration method may only be applied in cases where the entire pool may be handled as a unit; where a single operating organization controls the entire structure, or where all of the operators agree to a cooperative plan of pressure control for the entire field. One difficulty is that of finding an extraneous source of natural gas for repressuring purposes. Compression costs need not be more than two to five cents per thousand cu. ft., but if the gas used must be purchased at high cost from outside sources, the investment in gas tied up in the process may be economically prohibitive. However, most of the gas will be later recovered, possibly at a time when it commands a unit price higher than that at which it was purchased. Hence a profit may be made on the gas though there is necessarily a considerable delay in its realization. A large part of the production may be brought to the surface by inexpensive flow methods when this system of exploitation is used.

3. Gas Driving. This involves injecting gas into the reservoir rock through one well, causing it to migrate through the producing formation to another well, which is operated as a producer. In its movement through the reservoir rock the injected gas carries with it some of the residual oil, thus prolonging the productive lives of the wells and stimulating the ultimate recovery. Several different variations of the gas-drive process are in use involving arrangement of the injection and producing wells in different geometric patterns and different methods of control of the injected gas. Where gas is not available in sufficient quantity, compressed air may be used.

This is the best known of the gas injection methods and it has already found extensive application in many of the older, partially depleted American fields. Hundreds of properties and many thousands of wells are now being operated by this method in Pennsylvania, West Virginia, Ohio, Oklahoma, Kansas and Texas. While the method is well known to oil producers, it is applied in rather primitive fashion by most operators, and it would appear that there is considerable opportunity for increased efficiency in most cases. Possible improvements lie particularly in selective pressure control in different component members of the reservoir rock to avoid by-passing of beds containing much of the residual oil by the gas. Where there are marked variations in permeability in the different component members of the reservoir rock, the gas is likely to flow chiefly through the more permeable beds, leaving the less permeable strata untouched. The latter are also likely to have escaped drainage during the period of primary exploitation and often contain a large percentage of their original oil. Gas may be forced into the less permeable beds, if their position is accurately known, by setting packers on a multiple system of telescoping tubing strings in such manner as to prevent access of the gas to the more permeable beds; or by isolating each producing interval so that gas under appropriate pressure may be forced into it, without regard to the pressures used on other producing intervals. Pressures applied to different intervals may thus be proportioned to their relative permeabilities and a uniform rate of advance of the injected gas through the reservoir rock attained.

Where intelligently applied, the gas-drive process has seldom been unsuccessful in increasing the rate of production of an oil-producing property, and in many cases substantial increases in ultimate yield have been realized. An increase in the rate of production is usually observed soon after the process has been applied, and the increase continues for many months or years until a peak is reached. Decline from the production peak is often slow, so that stimulated production may continue over many years. In some instances, production has been maintained at a stimulated rate for fifteen years or more. Estimates by competent authorities, of increased ultimate yield, vary from 25 to 100 percent of the natural primary yield. An advantage of the gas-drive process is found in its universal application. Under almost any circumstances it will increase recovery efficiency to some extent. Furthermore, it can do no serious damage to the producing formations, leaving the partially depleted oil reservoir rock in condition for application of other methods.

Retrieving oil that would otherwise stay in the ground with a semi-portable cable-drilling rig, used in drilling "five-spot" wells for application of secondary recovery methods, northern Pennsylvania.

Applicability and Efficiency of the Water-flooding Process

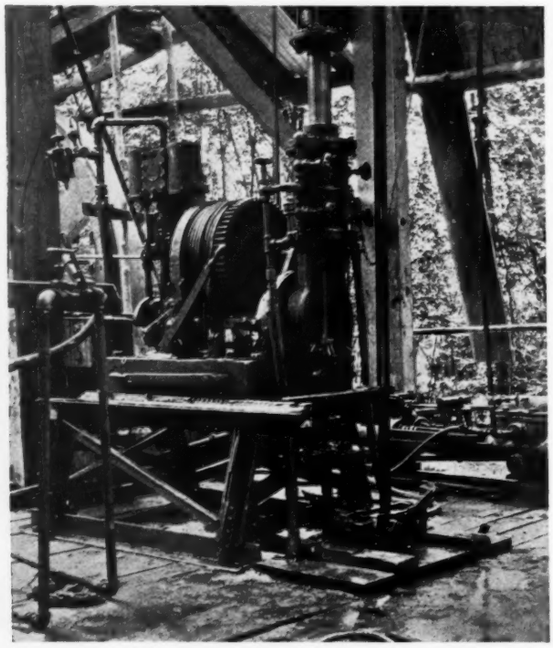
This method involves forcing water into the reservoir rock through one well or

Gas compressor plant and low-pressure gas-intake mains, Sugarland Field, Texas.

a series of wells arranged in appropriate geometric pattern, causing the water to flow through the reservoir rock to other near-by wells which produce at an accelerated rate. As the water progresses slowly through the reservoir rock, it gathers ahead of its advancing front a bank of oil which is eventually forced from the reservoir rock into the producing wells. If the flood advances uniformly through the reservoir rock, the rock pores are left filled with water, the capillary-held oil previously occupying a part of the pore space being largely displaced.

None of the gas-injection methods of recovery have any important influence on the volume of adherent oil retained by the reservoir rock, operating primarily in reducing the percentage of capillary-held oil. Water flooding, on the other hand, may under favorable circumstances recover a large part of both the capillary-held and adherent oil. Processes of recovery based on use of flowing gas can never be expected to recover in field practice more than about 40 percent of the oil initially present. Water-flooding may be considerably more efficient, laboratory tests indicating a recovery fully 20 percent greater under comparable conditions. Under ideal conditions in laboratory apparatus, recoveries as great as 80 percent of the original oil content are sometimes realized.

Diamond drill, used in coring oil sands in a northern Pennsylvania field.



The water-flooding process has been successfully applied throughout large areas in the Bradford-Alleghany district of northern Pennsylvania and southern New York and the operations have in some cases been highly profitable. For a time, many thought that the method was successful because of peculiar conditions existing in the reservoir rocks in these areas, and that water flooding would not be widely applicable to other fields. However, investigations have lately shown that conditions in the Bradford field are not unlike those in many other fields, and recently the process has been introduced into Oklahoma and north Texas fields.

As in the gas-drive process, one of the principal difficulties experienced in application of the water-flooding process is that of avoiding by-passing of water through the more permeable channels and component strata of the reservoir rock, leaving untouched the less permeable and more highly saturated strata and lenses of tight reservoir rock. Progress is being made in partially overcoming this difficulty by a process of delayed operation of the recovery wells, in which the fluids in the reservoir rock are maintained under elevated pressure from the injection before the recovery wells are opened for production. It would also seem to be feasible to control the relative volumes of water entering different component members of the reservoir rock and the injection pressures maintained on them, by setting packers on telescoping strings of tubing in such manner as to isolate different producing intervals from each other.

An important disadvantage of the water-flooding method is that it leaves the reservoir rock water-logged, with such residual oil as it still contains unproducible by any other methods of recovery now visualized. Due to present-day inefficiencies in application of the flooding process, much oil is being left behind in flooded areas that will probably never in future be recovered by any method. Competent authorities state that present practice in the Bradford field is recovering only 40 percent of the residual oil after primary exploitation, from 5,000 to 20,000 bbl. per acre being left in the reservoir rock. To the extent that the method fails to recover all of the drainable oil, it is destructive and is responsible for actual physical wastage of petroleum resources. Its use should only be permitted where there is assurance that the method will be intelligently applied and that a reasonably high percentage of the original oil will be secured.

In comparison with gas-injection methods of recovery, the water-flooding process also has the disadvantage of relatively high cost of application. Wells must generally be more closely spaced in water-flooding and the per-acre development cost is therefore greater. However, wells may be more widely spaced if higher injection pressures are used, and if a higher recovery per-acre is secured the unit production cost may be no greater than by gas-injection methods.

Applicability and Efficiency of "Oil Mining"

A CONSIDERABLE part of the inefficiency of methods of oil-field exploitation, in which petroleum is produced through wells, is due to the comparatively small surface of reservoir rock exposed in the walls of the wells through which all oil must be drained. Enlarging the surface area exposed for drainage greatly increases recovery efficiency, reducing flow resist-

ance through the reservoir rock and permitting a greater ultimate oil yield. Driving mine openings directly into and through a partially depleted oil reservoir rock affords direct access to the areas in which most of the residual oil is concentrated, and develops a maximum area of exposed surface to promote drainage. Instead of having to seek an outlet through restricted converging channels focusing on the comparatively small wall area provided by one or a few wells, with necessarily high flow resistance, the much larger areas of mine drifts permit the oil to flow toward the drainage surfaces along parallel lines offering comparatively little resistance. Expulsive forces within the reservoir rock may have reached an equilibrium with the forces resisting movement of fluids into wells, and yet contain sufficient residual energy to move large volumes of fluid into penetrating mine drifts.

The problems and hazards incidental to the conduct of mining operations in sands containing petroleum and low-pressure natural gas have all been satisfactorily solved in the mining enterprises at Pechelbronn and Wietze, and there seems to be no reason why the mining method may not be successfully applied to many or perhaps most of our partially depleted oil fields. Conditions more favorable than those presented at Pechelbronn for application of this method are found in many American oil fields, and only the comparatively low price commanded by American petroleum during the last decade and the plentiful supply of petroleum from recently discovered flush fields, have prevented the inauguration of oil mining enterprises in the Appalachian and Mid-continent regions of the United States. Cost of producing oil in the Pechelbronn and Wietze mines has ranged from $2 to $5 per barrel. However, the sands in these fields are thin and poorly saturated and it is believed that under more favorable conditions, such as might readily be found in certain American fields where the cost of mine development could be spread over a greater production, oil could be produced at a profit at present American price levels. Mining operations are necessarily costly and require a large capital investment which can only be justified by the large ultimate recovery that the method is capable of achieving under favorable conditions.

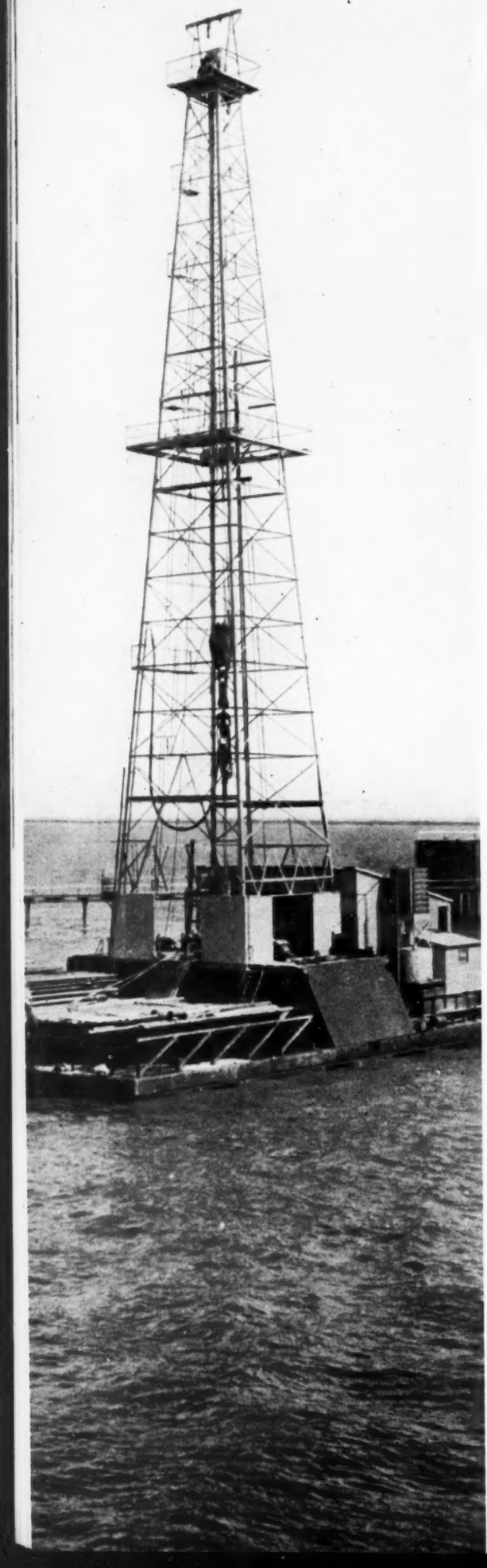
Best results would be secured in an oil mining enterprise in fields where the reservoir rock is a sand or poorly consolidated sand-stone, where primary exploitation through wells has left the productive formation well saturated with oil, but largely gas-drained. Depth is only an economic barrier, it being technically feasible to carry on mining operations to depths of many thousands of feet, but costs are moderately higher at greater depth. Higher recoveries of the residual oil are secured, and unit costs are therefore lower, when the oil is of low viscosity and the reservoir sands highly permeable. The sand strata are preferably continuous and free from shale partings, stringers, cross-bedding and other lithologic and stratigraphic irregularities that tend to prevent free drainage of the rock fluids. The oil sands and the overlying formations should be free of high-pressure water. If present in the oil sands, water will take possession of the drainage channels and create difficult recovery problems. If high-pressure water is present in the overlying formations, shaft-sinking operations are made more difficult and costly.

Another gas-injection well, in Olney Field, Texas, showing casing and tubing head equipment.

CHOICE OF SECONDARY METHODS. The selection of one or another of the several methods of secondary exploitation for use in a partially depleted field will involve careful study of the limiting conditions presented, and estimates of rates of recovery and ultimate recoveries that might be expected by each of the possible methods. Of the possible methods, the one finally selected will, of course, be the one that can be applied with maximum profit.

Some of the methods, such as the pressure-maintenance method and the pressure-restoration method, are appropriate for use only when property is held in large tracts. Preferably, the entire pool should be operated as a unit or should be controlled cooperatively. These methods are particularly applicable in regions where gas produced from flush fields has no adequate market and gas storage for future use is a secondary objective. The water-flooding process can be employed only in certain areas where its use has been authorized by law or by state regulatory officials; otherwise, neighboring operators whose properties may be adversely influenced by flooding operations may secure legal redress. Unless there is assurance that water flooding can be used more advantageously than any other method it should not be employed, as it prevents future use of possibly more effective methods, such as oil mining. Gas driving is applicable under nearly all circumstances, and would normally be the method selected unless some other more efficient method is also applicable. Drainage through mine openings involves technical practices unfamiliar to most oil producers, and because of the large capital investment required, most operators are reluctant to attempt it.

From the standpoint of gross cost of application, the mining method is most costly. Water flooding is probably next in order of cost, followed by pressure restoration, gas driving and pressure maintenance. However, the unit production cost by these several methods will depend upon the recoveries secured and the most costly methods may, under favorable conditions, be most efficient and lead to the lowest unit production cost. From the standpoint of recovery efficiency, in their present state of development, drainage through mine openings easily ranks first, followed in order of recovery efficiency by water flooding, pressure maintenance, gas driving and pressure restoration.



A striking tidal-wave effect created by the launching of a single-hull slotted barge, shown just at the moment of first hitting the water. At left a submergible drilling barge resting on bottom in eight feet of water in the Gulf Coast area.

Submergible Barges for Gulf Coast Drilling

By G. L. McBride

The Texas Co.

THE competence and efficiency of submergible drilling barges, as used in the lakes and marshes of the Gulf Coast, seem now well established. During the last four years, they have undergone the necessary period of trial and rearrangement until, now, what will probably become a more or less standard design has been arrived at. There are at present a fleet of twelve operating over a wide coastal area; from the very mouth of the Mississippi they are spotted westward to within a few miles of the Texas border.

In designing the original submergible drilling barge, and bearing in mind that the scheme was experimental and somewhat problematical, the unit was constructed of two standard and salvageable transportation barges paralleling each other, separated by eight feet and unified by deck trusses. Had the project failed, the only substantial loss would have been that of superstructure.

Prior to the development of the drilling barge, it was common practise, and still applies to most operations, to drive piling in lakes, or build mat jobs in swamps.

In that the barge was developed primarily to replace piling operations, it would probably be well to enumerate some of the more costly phases of lake drilling from pile driven structures.

The teredo-infested waters of the Gulf necessitate the use of creosoted timbers. A rig foundation calls for 260 piles of 45, 50 and 60-foot lengths, averaging $30.00 each, or $7,800.00 worth of piling. Cost of driving these piles averages $9.00 per pile, or $270.00. Pulling costs vary from $5.00 to $10.00 (the latter being contract price), and depreciation of piling due to cutting and driving from well to well amounts to $7.00 per pile. The drilling barge demands but 14 piles, and effects a saving of $5,040.00 per well.

There is required 44,000 board feet of lumber costing some $2,200.00 to floor, cap and brace a piling job to which should be added $660.00 as the cost of labor. Part of the lumber is salvageable, so the net saving effected by the permanently built drilling barge is conservatively $1,400.00.

The extremely corrosive, salty atmosphere of the Gulf tends to destroy pipe, valves and fittings very quickly. This is especially true in the case of portable rigs where connections are torn down, transported and rebuilt. On the drilling barges this equipment may easily be kept painted and its useful life greatly increased. On the water, tools are more easily lost than on land—each rigging up job shows innumerable small tools, tongs, wrenches, lights, cable, etc., far in excess of drilling barge requirements. Past estimates allowed a differential of $1,600.00 in favor of the barge, but with

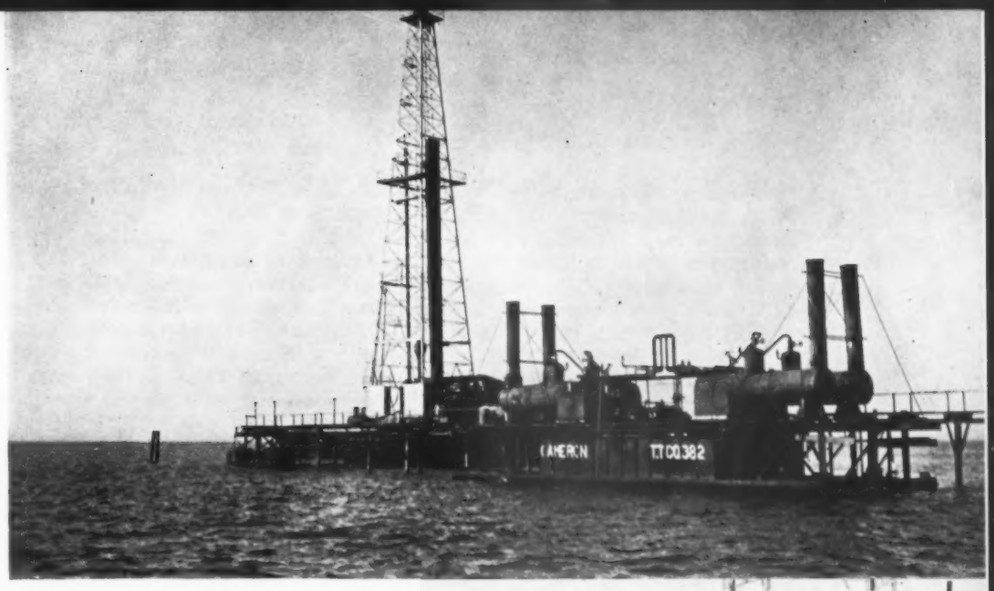
usage of 350 lbs. steam requiring costly valves and connections, the actual saving is probably much higher.

With the elimination of the work of erecting and dismantling derricks, setting and tearing down of mud, fuel and water tanks, the drilling and boiler barges immediately save $800.00.

Records of eight representative pile-driven wells show an average of ten days for rigging up and seven days for tearing down. High winds and rain, which are more usual in Gulf Coastal areas than elsewhere, contribute to delays in this type of work. Rarely is a drilling barge delayed in making a move, and it is a frequent occurrence to complete one well in the morning and spud in on the next well within sixteen hours.

When it is considered that during the average of sixteen lost days attributable to rigging up and tearing down there are additional costs, such as barging and boating, maintenance of camp, cook and helper, emergency stand-by lugger with pilot and gasoline expense, daily trips by foremen during construction, and proportionate cost of all boat-house and district overhead expense, the saving accomplished through elimination of the above has been estimated to amount to $4,918.00, the figures being taken from average of a number of wells.

Considering only the economies referred to above, there is realized a saving of approximately $15,000.00 per well with the drilling barge.

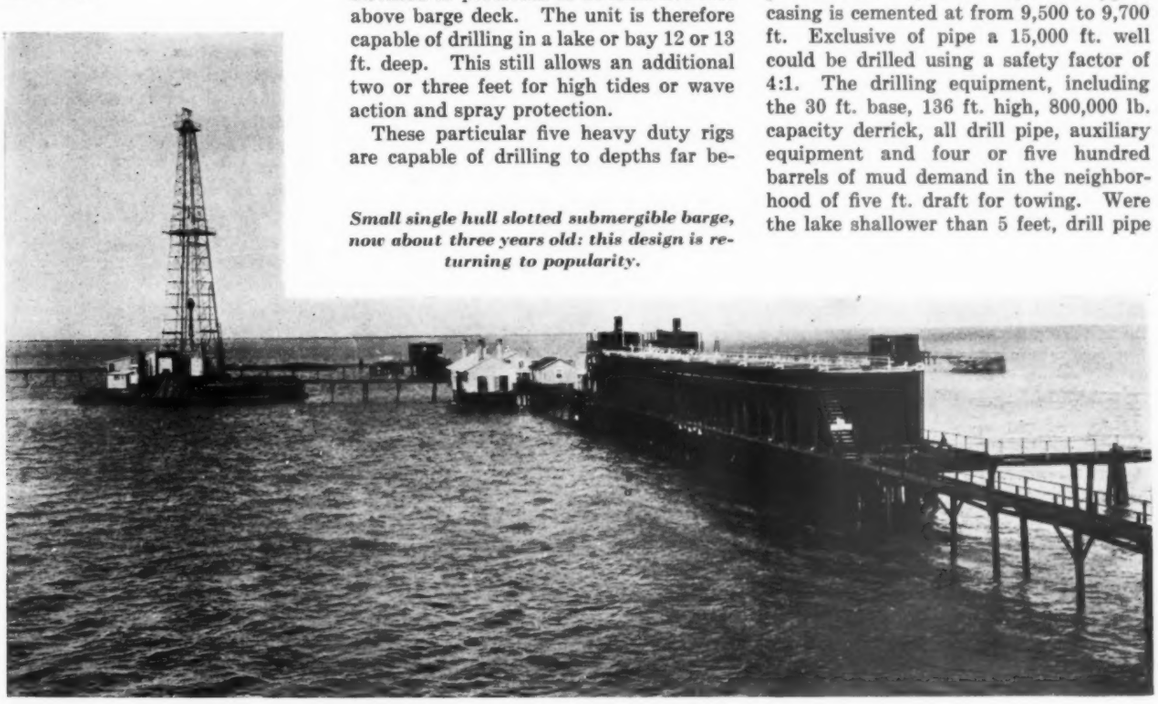


One of The Texas Company's boiler barges in the Gulf Coast district, before erection of building. The view on the right shows pipe racks, engine-house floor and the base of the derrick.

As against removing the entire assembly of a conventional pile-driven foundation—piece by piece—including piling, the twin-hull submergible drilling barge shown in the accompanying illustration may be raised in a few hours and the entire rig towed away intact, by a 40 horse-power tow boat.

Five of the larger type twin-hull drilling barges are in active use. The hulls are 10 ft. deep, while pipe racks, mud ditch, slush pit and pump compartment are elevated or protected to at least five feet above barge deck. The unit is therefore capable of drilling in a lake or bay 12 or 13 ft. deep. This still allows an additional two or three feet for high tides or wave action and spray protection.

These particular five heavy duty rigs are capable of drilling to depths far beyond the limitations of present drill pipe or casing. Five wells have been completed at Lafitte, Louisiana, where 7⅝ in. casing is cemented at from 9,500 to 9,700 ft. Exclusive of pipe a 15,000 ft. well could be drilled using a safety factor of 4:1. The drilling equipment, including the 30 ft. base, 136 ft. high, 800,000 lb. capacity derrick, all drill pipe, auxiliary equipment and four or five hundred barrels of mud demand in the neighborhood of five ft. draft for towing. Were the lake shallower than 5 feet, drill pipe



Small single hull slotted submergible barge, now about three years old: this design is returning to popularity.

and mud could quickly be removed, and draft reduced to about four feet. For lakes or bays shallower than four feet the operator must resort to dredging.

An accompanying illustration shows the general arrangement. In the foreground are the pipe racks. The lower part of the derrick is shown, as also, the unusually large derrick floor (30 x 44 ft.). In the background is the steel floor of the engine house, while immediately under the engine house are the slush pit and pump compartments. The trusses shown just under the derrick legs carry the entire rotary table and floor load, and transfer it evenly over both barge decks (there is no vertical posting under the rotary), while the barges themselves are longitudinally framed to spread loading over entire barge bottom.

Most recent twin-hull barges are 56 ft. x 120 ft. over-all, with hull 10 ft. deep and superstructure 11 ft. high. The unit is designed to support 7,000 ft. of 7⅝ casing stacked on either side of the table while at the same time 10,000 ft. of 4½ in. drill pipe hits the table with a 50 percent additional shock load.

Boiler barges are also shown in an accompanying illustration. Four 125 HP 350 lb. steam pressure oilfield boilers are mounted on a barge whose width is limited to 28 ft. for transportation through narrow canals and bridges. If necessary the twin hull barges can be dismantled and separated, width then being reduced to 24 ft.

Beneath the boilers is the 1,000 bbl. water storage tank which eliminates necessity for erecting storage.

Cost of the barges varies considerably. A single hull slotted barge designed to drill to 5,000 ft. can be built for $11,000.00. Similar barges for 8,000 ft. drilling cost $16,500.00. A twin-hull barge capable of 10,000 ft. drilling costs $26,000.00, while one for 15,000 ft. will amount to $31,500.00. A single hull model designed for 15,000 ft. drilling should cost between $22,000.00 and $25,000.00.

The above costs include superstructure, pipe racks, reserve mud pits, mud pump and slush pit, engine foundation, stairways and walks, spuds and all interior valves and controls.

A boiler barge, including superstructure and reserve water tank costs approximately $9,000.00.

The advantages of the drilling barge over pile-driven foundations may be summarized as follows:

1. Greatly reduced drilling costs.
2. More wells per year per rig, which means more and earlier production.
3. Reduced fire hazard. The flooring is the only wood on the unit.
4. A far stronger and more reliable foundation for water and swamp areas.
5. Reduced rig maintenance. Being permanent the crews take splendid care of the machinery.
6. They are unaffected by fairly high winds, waves and storms.
7. In case of blow-out and crater, equipment is floated away as against being lost.
8. Permit delaying choice of subsequent location till drilling well finds the oil-sand. A distinct advantage in the case of piercement type domes.

▼

Efficiency of Steam Power

(Continued from page 228)

to the end of the stroke since no flywheel effect is available. This eliminates all possibility of using any of the expansive force of the steam and the steam used by the steam end is measured entirely by the volumetric displacement of the steam pistons. The resulting steam consumption of the direct acting duplex pump is, therefore, approximately 60 lb. per hydraulic horsepower per hour.

In order to effect heat conservation at this point two types of slush pump prime movers have been used. The multi-stage, high speed steam turbine driving through reduction gears has been used with satisfaction from a steam economy standpoint but the characteristics of this type of prime mover are not entirely favorable since constant torque is not available at all speeds and since the low speed or stalled torque is not sufficiently high. Any slush pump and its prime mover must be capable of developing the highest possible mud pressure when stalled if it is to be most successful from a field operating standpoint. The steam engine as a prime mover meets all the torque requirements of a slush pump drive and if of the correct size for the work will have an equally favorable steam consumption as the multi-stage non-condensing turbine. The steam engine can be either of the single cylinder or twin cylinder type and either direct coupled to the pinion shaft of a power slush pump or drive it by V-Belt drive.

If the load required of the particular size of steam engine chosen is such that the engine will carry the load at 30 percent cutoff the steam consumption will be approximately 30 lb. per hydraulic horsepower per hour as compared with a steam rate 60 lb. on a direct acting pump. This is decidedly in the direction of heat conservation. If the load on the engine is such that a cutoff greater than 30 percent is required the steam consumption may reach a maximum of 40 lb. per hydraulic horsepower per hour and even this figure represents a 33⅓ percent reduction in the steam consumption of the slush pump. According to the A.S.M.E. test of a rotary rig made in Oklahoma City in 1932 by Professor William H. Carson of the University of Oklahoma the steam used by the direct acting slush pump is about 70 percent of the total steam generated. It, therefore, will be seen that a steam engine driven power slush pump will conserve between 25 percent and 35 percent of the total steam used.

Up to the present time it has been the universal practice to drive the rotary table with the hoisting engine through chain drives from engine to hoist and from hoist to rotary. The power required to drive the rotary table is relatively small compared with the capacity of the hoisting engine and the engine, therefore, is operating at a very uneconomical load factor when driving the rotary table. This is especially true if the engine is not equipped with a device for shortening the cutoff so as to realize some steam economy from the expansive force of the steam and reduce the inefficiency due to throttling. In order to effect improvement at this point one manufacturer has developed a separate steam engine drive for the rotary table. This engine is much smaller than the regular hoisting engine and, therefore, operates at a favorable load factor at all times. It is equipped with cutoff control and is reversible. The engine is direct connected to the rotary table through a gear box of suitable ratio to provide the desired range of rotary table speeds. It is of the twin vertical, high speed, piston valve type and is mounted on a rigid self-contained structural frame along with the rotary table so that the entire assembly is moved as a unit and kept in alignment. Since the rotary usually develops a maximum load equal to the capacity of the engine and a choice of cutoff is provided for the lighter loads, it is estimated that a saving of steam of approximately 20 percent of that ordinarily required for driving the hoisting engine for drilling will result.

An Infallible Eye 9000 Ft. Down

Instruments Have Now Been Perfected Which Furnish an Accurate Picture of the Direction of Drill Hole Enabling The Operator to Control Direction.

By G. L. Kothny

In the Superior Court of the State of California, in and for the County of Los Angeles.

Alphonzo E. Bell Corporation, a corporation, et al., Plaintiffs, vs. Bell View Oil Syndicate, et al., Defendants.

(1) One who drills an oil well on his own land and permits the drill to drift 1,500 feet away into the lands of another and with knowledge of the bottom puts the well on production is liable for trespass and for conversion of the oil taken from the stranger's land.

(2) The fact that at the time of the drilling of such well the facilities and appliances had not been perfected and the knowledge of drilling had not advanced so that directional drilling was an art and the drilling of straight holes was unknown, did not justify an operator in drilling into strange lands at a distance of 1,500 feet from the surface location and placing his well on production at that point, notwithstanding the pool produced from extended into the lands of the drilling party.

(3) Where a fraud is committed by an underground trespass concealed at the time of the commission and concealed for eight years thereafter from the injured party, the statute will be tolled, notwithstanding scouts may have had access to the derrick and the log books of the driller.

In view of one of the points raised by Mr. Kothny in the accompanying article, the above ruling of the Superior Court is interesting as an indication of the importance of accurate well surveys.—Editor.

ABOUT ten years ago the production industry awakened to the fact that crooked holes were a common occurrence and that the results of crooked holes were detrimental and affecting every phase of development and producing operations.

This realization brought about a considerable activity in creating more reliable underground well surveying instruments than those known and used at that time. The close relationship between oil producers, engineers, and scientists made possible the development of well surveying instruments giving accurate and reliable records, records which now are being accepted by the courts in underground trespass cases.

The existence of well surveying instruments giving reliable information regarding the true course of the hole has made possible the development of the directed drilling (controlled steering of the drill stem), which during the past three years has been reduced to a practical art, enabling the producers to complete their holes at any point within a reasonable horizontal distance from the derrick location.

Well surveying and controlled directed drilling are closely related. Directed drilling cannot be executed successfully unless there is available an accurate and reliable survey of the existing course of the hole, and a reliable surveying instrument for checking the setting of the deflecting tools and the progress of the directed hole to its objective.

A reliable and accurate survey can be obtained by the use of an automatic, self-checking, gyroscopic well surveying instrument, which is not subjected to magnetic influences underground, by ore bearing strata or by lost piping or tools, and the accuracy of which is also not affected by the tortuosity, torsional resistance and human errors in sighting, which may occur if the method of drill stem orientation is being used in making a survey.

The instrument illustrated in Figure 1 uses a gyroscopic, directional indicator for recording the true North-South direction. Use of the second property of the gyroscope, the precession, is made in compensating the gyroscope for the earth rotation. The gyro pointer is oriented to a true North point and balanced so that it will remain true North during the survey.

To the face of the gyroscopic case, illustrated in Figure 2, are attached an accurate clock and a thermometer. A surface clock, identical and synchronous with the instrument clock, is used for recording the time at certain depth intervals, thereby correlating each exposure with the depth at which it was taken. The inclination is recorded either by a spherical box level gauge, or by a pendulum inclination unit. Between the gyro and the box level gauge is arranged an unique movie film camera, shown in Figure 3, with two lens barrels pointing in opposite directions, one towards the face of the gyro, the other towards the box level gauge. This camera is operated by an electric motor and controlled by a timing device, which also controls the illumination necessary to take the pictures at desired depth intervals.

The camera uses 50 ft. of 16mm. film and has a capacity of about 1000 records. It superimposes one picture upon the other so that a combined record, as shown in Figure 4, of inclination and direction is secured. These records are made while lowering the instrument into the hole and also while bringing it out of the hole, hence duplicate records at all depths are obtained, providing a check. When the instrument is returned to the surface, the film is developed and the records, enlarged by a projector, are interpreted and a map of the hole is drawn.

The instrument is enclosed in a case of heavy steel tubing, so constructed as to resist the large hydrostatic pressures encountered when lowered into the hole. In cased holes the instrument is lowered on a 9/16 in. wire line; in open rotary drilled holes the instrument is lowered on the drill stem or tubing as fast as the drilling crew are able to assemble or disconnect the stands. Records are being taken while the drill pipe is at rest in the slips.

The time required for an in and out survey of a 9,500 ft. hole is about three and one-half hours if the instrument is lowered on the wire line and if lowered on the drill stem, the time required will correspond to that of a round trip with the drill stem. In California, holes of 9,500 ft. depth have been surveyed on the in and out run on the drill stem in seven and one-half hours.

The instrument can easily be transported as it weighs only 45 lbs. The weight of the protective steel tubing is approximately 1,300 lbs. The gyroscopic instrument can be operated by any technically trained person with production experience after a brief training. The out-

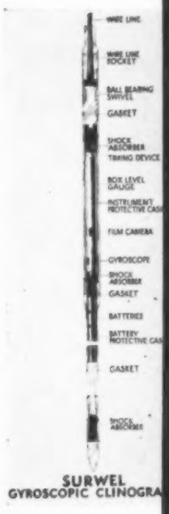


Figure 1

Figure 2

standing advantages of this instrument are:

1. Its speedy operation.
2. The automatic recording. The data obtained is not affected by human errors.
3. It makes two surveys in one round trip providing a positive check.
4. It permits the making of confidential surveys. The gyro pointer can be oriented in any desired direction, known only to one person.

The data obtained through the survey will provide all information necessary for planning correctional measures and directional drilling.

To check the settings of the deflecting tools and the progress of the directed hole to its objective, it is not necessary to have an instrument giving continuous records. Only a single reading of the direction and inclination is required. Various types of Directional Single Shot Clinographs have been developed. The majority of them use a magnetic needle or a compass for directional information and a plumb bob for inclinational information. The records are made photographically on sensitized paper.

The instrument shown in Figure 5 is distinct from the many others available, having:

1. A floating compass, elastically supported by its buoyancy, not requiring latitudinal adjustment nor being subject to inaccuracies resulting from cracked jewel bearing or friction in gimbals, able to withstand the most severe abuse which it may meet when being lowered into the hole.
2. A plumb bob cross hair suspended by three universally mounted arms, making the plumb bob unit more rugged and infallible under abuses, also reducing the swinging period of the pendulum.
3. Recording a photograph of the floating compass superimposed by a shadograph of the plumb bob cross hair, giving extreme accurate and self-checking results.

The instrument as well as the protective casing are made of non-magnetic materials. It is used in open holes only, being lowered on a sand or bailing line at speeds ranging from 400–800 ft. per minute. It is allowed to rest for about four minutes at the depth at which the record is to be taken, after which it is pulled out of the hole. The record is available within five minutes after the instrument has come out of the hole.

The operation of single shot instruments is extremely simple and does not require any special knowledge of photography. Daylight loading and daylight developing devices are furnished with the instrument as well as all necessary photographic and electrical supplies, all of which are contained in a conveniently arranged metal case.

The record obtained gives degrees of inclination off the vertical, also the magnetic North, as illustrated in Figure 6. To read the direction, a celluloid disc with a hair line is furnished, which hair line is run through the center of the disc and the intersection of the cross hairs of the plumb bob and is extended to the bearing graduation at the outer circumference of the disc.

The inclination units are interchangeable to meet with an extreme degree of accuracy every condition that may be encountered.

With a ten degree inclination unit, angles as small as one quarter degree can be easily and accurately measured, and the direction is measured within one degree on any inclination unit.

Figure 3

Instruments are available in two sizes with an outside diameter of the protective casings of three and one-half inch and one and eleven-sixteenth inch. The smaller size instrument can be used advantageously in connection with Barrett-Robishaw or other similar type core barrels.

After removing the core barrel and raising the drill stem about 15 to 20 ft., the instrument is lowered through the drill collar to the bottom of the hole and a record is obtained, without making it necessary to pull the drill stem completely out of the hole. Considerable saving in time is obtained with this method of operation.

Directional magnetic single shot clino-

Figure 4

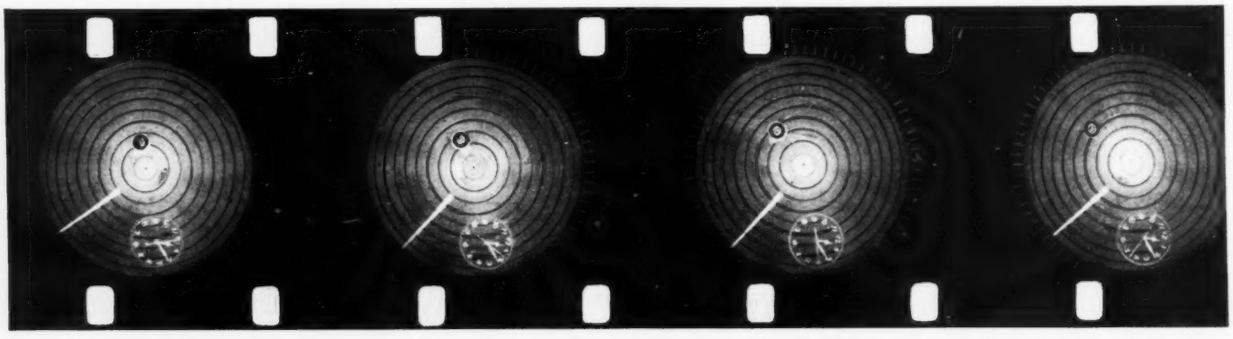


Figure 6

graphs receive considerable abuse in the hands of the drilling crew and it is therefore advisable to have these instruments checked and serviced at regular time intervals. These instruments are usually rented on a daily or monthly basis in the United States. The rental fees cover furnishing the instrument, the accessories, as well as a liberal amount of photographic and electrical supplies free per month; they also cover the inspection service and free replacements, making available to the renter at all times accurate and reliable recording means.

Computations of continuous or single shot surveys are usually made by the Latitude and Departure method. In this method it is assumed that the course length between two observation points is a straight line and the hypotenuse of a right triangle, the angle of which is the angle of inclination, and that this angle exist throughout the course length. Obviously this is not so because the angle changes gradually. But since records are usually taken at intervals of less than 100 ft., and since a change of more than nine degrees in the angle of inclination very seldom occurs in depth intervals of 100 ft. or less, this method is as accurate as can possibly be obtained consistent with good practice.

If records are obtained at greater intervals than 100 ft. or when the change of angles is great, or if there are large changes in the direction, corrective measures must be applied by assigning averaged angular increments to equally spaced sections of the course length.

Latitude refers to the position North or South, while Departure refers to the position East or West of the mouth of the well on the derrick floor.

To locate any point of the course of a hole it is necessary to know its true vertical depth, its latitude and departure.

The true vertical depth is obtained by multiplying the course length by the cosine of the angle of inclination (see Figure 7). The course deviation is the product of the course length by the sine of the angle of inclination.

The departure (East or West position), is obtained by multiplying the course deviation with the sine of bearing angle and the latitude (North or South position) is the product of the course deviation with the cosine of bearing angle (see Figure 8).

All these functions are tabulated in a working sheet such as illustrated in Figure 12, and from this data a map of the course of the hole in three projections, Horizontal, Vertical East West Plane and Vertical North South Plane, is plotted on cross section paper.

An examination of the results of several hundred surveys would indicate:

1. That there is not one absolutely straight hole.
2. That the majority of holes spiral in a clockwise direction, unless exceptional conditions exist.
3. That holes with very small angles of inclination spiral more than those with large angles of inclination.
4. That when reaching large angles of inclination, holes nearly always drift off in one vertical plane.

The information obtained from a survey together with the proper knowledge of the vertical depth of geological horizons, the hole's influence on the accurate contouring of the structure and the dip observed from core laminations form the considerations when planning controlled directed drilling.

Controlled directed drilling accomplishes two purposes and is used as a corrective measure, and as an economic measure to save expenses and secure more oil production.

As previously stated, one of the rarest things in the oil fields is a perfectly straight hole. The bringing back of a hole that has wandered away from the vertical to a point beneath the derrick, may be considered a corrective measure. So may be considered the redrilling (to the same producing horizon), of a hole which has ceased production and when surveyed was found to be bottomed in the wrong place.

The uses of controlled directed drilling as an economic measure are many fold.

There are oil fields located off shore under the ocean or under lakes or river beds, which to penetrate would cost huge sums of money. In fact, the cost of constructing piers, sometimes as much as one-half mile out into the water, the cost of providing adequate foundations to support the drilling platform and derrick, and finally the cost of supplying transportation to the point of operation can easily exceed the actual cost of drilling the well.

Obviously, elimination of pier, foundation and transportation costs would represent big savings. Directed controlled drilling makes such savings possible. By virtue of this method, convenient spots near the shore can be selected from which the drilling can be directed at an angle to the oil sand located beneath the sea, as shown in Figure 9. The history of directed drilled wells in the Huntington Beach field in California with more than thirty wells bottomed within an area of slightly less than twenty acres under the Pacific Ocean with angles of inclination as high as sixty degrees, is well known.

If the pier method of reaching a submerged location is found necessary, directional drilling can still be employed advantageously. Instead of drilling one hole from one foundation and derrick, directed drilling makes it possible to drill several holes from one foundation. By directing the course of each hole, the submerged field can be penetrated over an area equal to that of six or seven individual locations. This method has been used with success by the Barnsdall Oil Company in the Elwood Field, California, where the greater portion of the productive area lies beneath the Pacific Ocean. When drilling two or more holes simultaneously or concurrently, there is also the possibility of running the drill pipe into an adjacent hole, when being pulled from another hole, thereby eliminating the necessity of racking the pipe and actually saving half the time of a combined round trip. The same principle of steering the drill pipe is also used to avoid undesirable geological strata or to reach oil sands located under overhanging salt domes. As is indicated in Figure 10 at the right side of the illustration, a vertical well may mean drilling through cap rock,

Figure 5

Figure 7

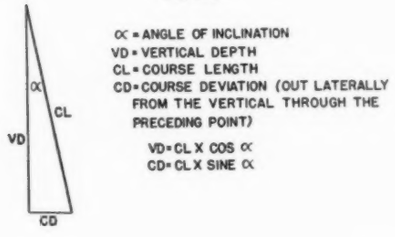
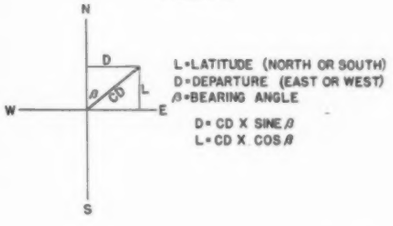

∝ = ANGLE OF INCLINATION
VD = VERTICAL DEPTH
CL = COURSE LENGTH
CD = COURSE DEVIATION (OUT LATERALLY FROM THE VERTICAL THROUGH THE PRECEDING POINT)
VD = CL X COS ∝
CD = CL X SINE ∝
∝
CL
VD
CD

Figure 8



SPERRY-SUN WELL SURVEYING CO.

COMPANY Blue Oil Co. WELL State No. 18

SURWEL TABULATION SHEET

SHEET NO. 1 JOB NO. HOU-378 DATE 2-3-36

CORRECTED TIME	COURSE LENGTH	TOTAL MEASURED LENGTH	ANGLE OF INCLIN.	VERTICAL DEPTH COURSE	VERTICAL DEPTH TOTAL	COURSE DEVIATION	OBSERVED DIRECTION DEVIATION	I E CORR	DRIFT	CORRECTED DIRECTION DEVIATION	COURSE LATITUDE N	COURSE LATITUDE S	COURSE DEPARTURE E	COURSE DEPARTURE W	TOTAL LATITUDE N	TOTAL LATITUDE S	TOTAL DEPARTURE E	TOTAL DEPARTURE W
											.59			.81				
											.18			.24				
											.01			.01				
1:38:52	100	100	3/4	99.99	99.99	1.31	N 54 W		0	N 54 W	.78			1.06	.78			1.06
											2.62			1.45				
											.79			.44				
											.03			.01				
39:31	100	200	2½	99.92	199.91	3.93	N 30 W		-1	N 29 W	3.44			1.90	4.22			2.96
											6.62			2.28				
											.38			.13				
											.01							
40:18	100	300	4½	99.73	299.64	7.41	N 20 W		-1	N 19 W	7.01			2.41	11.23			5.37
											7.61			2.47				
											.67			.22				
											.02			.01				
40:51	100	400	5	99.62	399.26	8.72	N 19 W		-1	N 18 W	8.30			2.70	19.53			8.07
											8.46			3.08				
											.47			.17				
											.08			.03				
41:31	100	500	5½	99.54	498.80	9.58	N 21 W		-1	N 20 W	9.01			3.28	28.54			11.35
											7.61		2.47					
											.67		.22					
											.02		.01					
42:08	100	600	5	99.62	598.42	8.72	N 17 E		+1	N 18 E	8.30		2.70		36.84			8.65
											6.62		2.28					
											.38		.13					
											.01							
42:50	100	700	4½	99.73	698.15	7.41	N 18 E		+1	N 19 E	7.01		2.41		43.65			6.24
											2.62		1.45					
											.79		.44					
											.03		.01					
43:33	100	800	2½	99.92	798.07	3.93	N 28 E		+1	N 29 E	3.44		1.90		47.89			4.34

CALCULATED BY J.S. CHECKED BY G.A.

which usually covers the salt, and then through salt and shale before reaching the oil sand. Drilling through cap rock and salt is accompanied by many expensive troubles and is something to be avoided. Directed drilling makes it possible to cut around such formations.

Directed drilling can also be advantageously used around objectionable situations, where the surface topography makes drilling at an angle from a lower location preferable to deeper drilling through a hill, as shown in Figure 11. As is readily perceptible, this method of tapping an awkwardly located field is very economical—many feet of unnecessary and expensive drilling is avoided, as well as the cost of building a road to the site and the cost of transporting drilling materials to the top of the hill.

Controlled directed drilling requires three things:

1. A deflecting tool.
2. An apparatus or instrument to orient correctly the deflecting tool.
3. An accurate and reliable surveying instrument to check the progress of the directed drilled hole.

The deflecting tools mostly used are the whipstock (permanent or removable), and the knuckle-joint, a patented tool having a universal joint incorporated below the tool joint. The selection of the proper tool is made according to the formation to be penetrated. The tool is oriented in and its correct position is checked by means of the gyroscopic well surveying instrument. When using a whipstock, a pilot hole is usually drilled first about fifteen feet deep below the whipstock, the direction and inclination of the new hole is checked with a Single Shot Clinograph, and drilling followed up 25 to 30 feet with a special bit on the the same limber pipe to enlarge the angle obtained from the whipstock. The pilot hole is then reamed to the proper size with a pilot reaming bit.

If the knuckle joint is used, the procedure is somewhat similar; after orienting the knuckle joint and having checked the correct orientation, the drill pipe is lowered a foot or two to apply weight and stab the point of the stinger into the formation to establish a definite beginning. Drilling is started with the point of the stinger taking the proper angle. When about 20 feet of hole have been drilled, the tools are removed from the hole, the knuckle joint is removed and other tools, selected according to existing conditions, are run to follow through the hole made by the knuckle joint.

The course and deviation of the new hole are checked frequently and the records obtained from the surveying instrument more or less control and direct every move in the controlled drilling.

Directed drilling is now extensively used for legitimate purposes in all rotary drilled oil fields in the United States. In the earlier days, this practice has been abused by a number of smaller operators, particularly in the Huntington Beach and Signal Hill Field in California. Recent judicial decisions, which were the outcome of actions brought by legitimate operators for protection against deliberate trespassers, have established that under present statutes the owners of a crooked

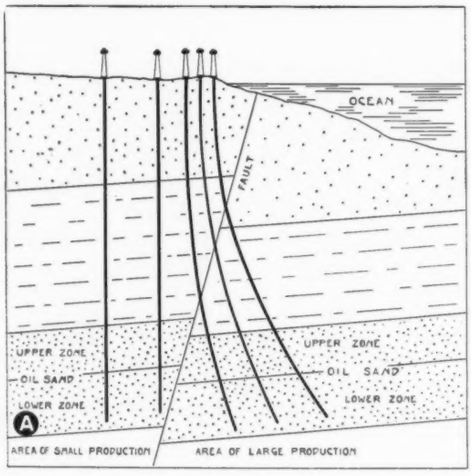


Figure 9

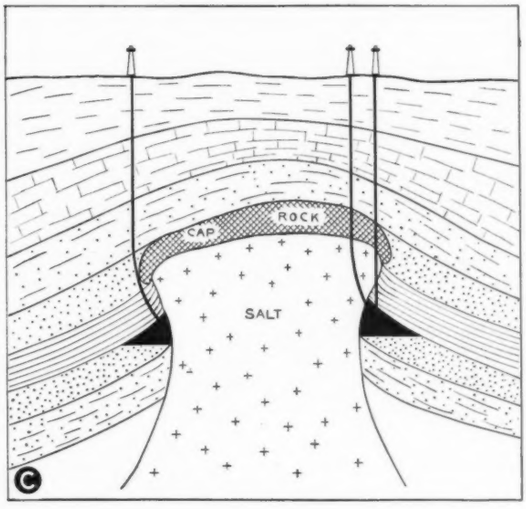


Figure 10

hole are liable financially for every barrel of oil they have taken from under the surface of an adjoining tract, whether the trespass was an innocent or willful one.

As a protection against becoming a defendant in a trespass case, it would seem advisable to have every edge well surveyed with the gyroscopic instrument described above. The accuracy and reliability of this instrument has been recognized by the courts and the records obtained from it have been used as prima facie evidence in trespass cases.

If a well is not drilled within the boundary of a property with the tools and instruments now available and with the experience attained by the petroleum industry, the operator either does not want to or does not know how.

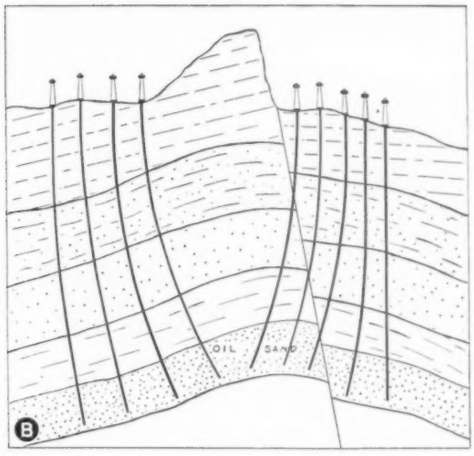


Figure 11

Foreign Oil Legion

Sir HENRI DETERDING celebrated his seventieth birthday on April 19th: May 15th marked the fortieth anniversary of his connection with the Royal Dutch Group. During those forty years Sir Henri has risen to foremost rank as a leading petroleum executive of a world wide organization which he directs as actively and ably today as he has throughout his two score year connection with that vast company.

The following cable, expressing tribute to his friend, was received from Walter Teagle:

"If a student wants a comprehensive understanding of the origin and development of the petroleum industry he can acquire it most interestingly by reading of the careers of two men still living. One of them 96 years old, and the other but 70. Sir Henri Deterding pioneered just as truly as did John D. Rockefeller. His work was to extend and enrich the Empire of Petroleum founded by his illustrious senior, and to make its products available to millions far removed from oilfields. He is a truly great man, always a builder, never a destroyer, whose vision, courage and abounding energy have inspired thousands of workers in advancing the outposts of Royal Dutch-Shell to the remotest quarters of the globe.

"W. C. TEAGLE."

B. P. Newton

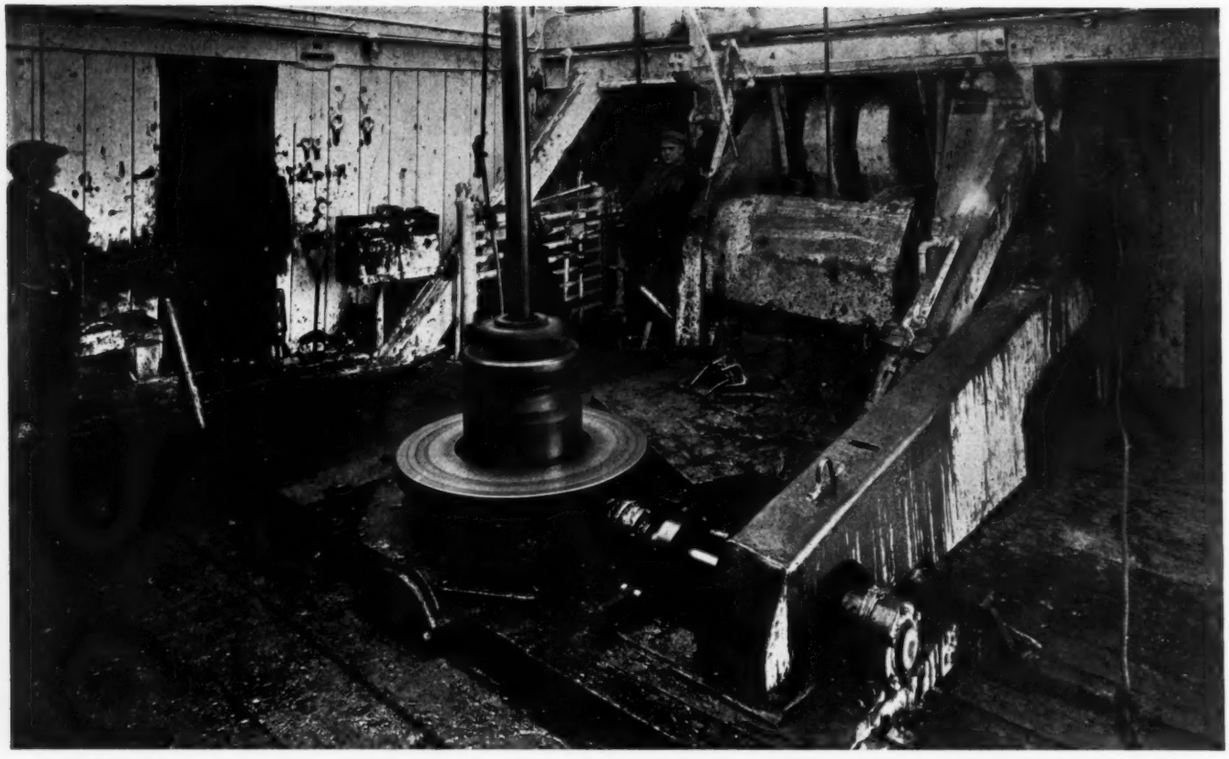
B. P. NEWTON for the past several years has been located at Antwerp in charge of Gulf's European marketing operations. Mr. Newton now has been transferred to the company's general headquarters in Pittsburgh and has been elected Vice President of the Gulf Oil Corporation. He is in charge of all export marketing operations and exercises executive control over the European subsidiaries. Mr. Newton's many European friends will be glad to know that the duties of his position will require frequent trips to their side of the Atlantic so that his genial personality will not be lost to them entirely.

Guy WELLMAN, Director of the Near East Development Corporation, and Mrs. Wellman, were passengers on the WASHINGTON which left New York on April 8th for Europe.

The Oil Industries Club gave their seventh annual ball at the Savoy Hotel on Thursday evening, April 23rd. The President, William J. Wigney, Esq., and Mrs. Wigney, supported by members of the Committee and their ladies, received members and guests, who numbered 500.

C. P. NEWMAN, managing director of Newman, Hender and Co. Ltd., Woodchester, England, is visiting the United States. Mr. Newman was a passenger on the BERENGARIA which left England on April 15th.

R. S. DRYSDALE, Sun Oil Co., left New York April 1 for Europe.



Reducing Pressure Drilling to a Science

Pressure Drilling Formerly Improvised in the Field as a Last Resort, Now Receives Careful Study and Advance Planning as to Technique and Equipment.

By James C. Fortune

The hydraulic rotary table above is drilling with a 4-inch drill pipe, in Canada. Below is a flow bean manifold on a well in Burmah.

ANY article dealing with the subject of pressure drilling should at the outset make clear just what is meant when using this term. *Pressure drilling, or pressure control, is a method of rotary drilling by which the drilling fluid is maintained in a closed pressure circuit.* The pressures may be as high as the ability of the equipment to withstand them, or as low as a column of aerated oil will produce; they may be derived from the well itself—gas, oil or water in the formation—or from an outside source, such as pumps in the pressure circuit. The drilling cuttings must be brought to the surface and removed while the closed circuit is maintained.

Pressure drilling permits the successful application of methods which otherwise could not be attempted with the conventional rotary system.

1. The hydrostatic head of any drilling mud can be increased without the addition of weight material.
2. The hydrostatic head of weight material can be further increased to as much as 2500 lb. per square inch.
3. Formation pressures such as gas, oil or water can be equalized by a combination of mechanical and hydrostatic pressure heads.
4. Drilling can be done without sealing off production, as pressure control permits using an aerated fluid column—with less hydrostatic head—than the bottom hole pressure of the well. The production increases are noted as the formation is be-

ing drilled and any water strata are immediately detected.

5. Chemically treated drilling fluids can be brought into closer contact with the formation, if greater penetration can be secured through greater pressure.
6. A well can be brought in with a controlled flow, where high initial velocities might cause heaving and caving, or otherwise disturb the producing horizon.

A review of past efforts in pressure drilling, where one or more of the above sets of conditions existed, will indicate what might be expected with pressure control methods being used by a trained personnel with complete and improved equipment.

In Mexico, oil was found in a porous lime at about 2000 ft. under 1100/1500 lb. pressure, at a volume capable of producing up to 150,000 bbl. per day through 8 in. casing. When drilled in with cable tools, wells were set on fire when the tools were blown from the hole: drilling cables were bunched in the valves and they were blown off the casing; tools were stuck in the hole and lines had to be cut before the valve could be closed; in many cases the wells could not be drilled in before the oil flow made it necessary to come out of the hole, and, if they were drilled in, formation being carried in the unrestricted oil flow would bridge the well, the casing or the well head connections.

Pressure drilling permitted balancing the fluid column in the well with the formation pressure, and the wells could be drilled as far as was desired into the producing limestone without any loss of production or blowing of formation. All fire hazard was eliminated.

In Trinidad, production was found in very fine silty shale and sand, at 3000/4000 ft. under 1000/2000 lb. pressure, overlaid by heaving shale and volcanic ash. With cable tools it was difficult to carry any length of casing in this formation, and open hole could not be carried ahead of the shoe. Rotaries could make unlimited hole, but the hole would be lost in the shifting formation while changing bits. When heavy weight material was added to condition the hole made, it also sealed off production. When the wells were flowed hard enough to clean themselves of the heavy drilling fluid, they often carried such quantities of silty shale and fine sand into the hole as to completely kill them. Redrilling in many instances would not bring back the production to anything like its original volume.

By pressure drilling methods, wells were drilled with a light drilling fluid and screen pipe set under pressure control. The wells were washed with water and finally oil with well pressures maintained in balance with formation pressures. When wells were put on production with a controlled flow—instead of being allowed to clean themselves—a minimum of sand was produced, with the oil and gas conserved, resulting in a much greater ultimate recovery.

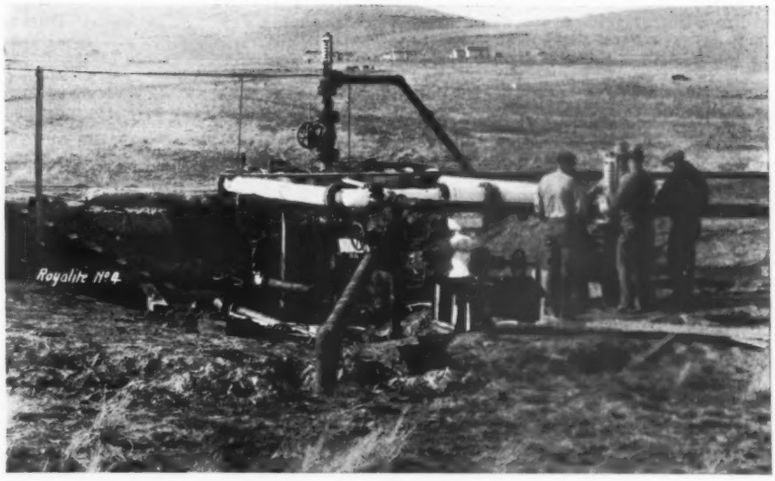
In Canada, oil was found in tight limestone at 5000/6000 ft. under a pressure of 2000/3000 lb. Gas expanding from the tight lime at the bottom of the hole, produced temperatures down to 75 deg. below zero. Drilling mud with a hydrostatic head to balance the formation pressure would freeze to ice in these low temperatures and stick the drill pipe. Oil as a drilling fluid became badly cut with the naphtha produced, and had a hydrostatic head below well pressure, as well as too little viscosity to carry ordinary rotary cuttings out of the well.

Pressure drilling equipment, by the combination of mechanical and hydrostatic pressure heads, permitted the use of oil as a circulating fluid. By using a hydraulic feed with the equipment, bit cuttings were fine enough to be carried in suspension in the lighter circulating medium.

The Khaur field in the Punjab, India, has probably the highest recorded pressures of any oil field. The formation is hard shale, with very poor mud-making qualities, interbedded with lenses of sand. Small production is found at a number of depths but the high pressures are met below 4000 ft. The salt water and oil originally sealed in the formation have been subjected to later geological movement which has put the whole anticline under tremendous pressure.

Pressures over 5000 lb. per sq. inch have been recorded, but the volume of fluid under these pressures is very small. An attempt to drill with ordinary rotary methods, using the heaviest weight material, was unsuccessful. When the pressure zone was penetrated, the formation backed by these high pressures, would "explode" into the hole, heaving up around the bit and sticking the drill pipe. A number of wells have been completed at Khaur using pressure control methods (WORLD PETROLEUM, April 1935). Well head pressures were carried to the point of creating a condition of balance, where the well would neither make nor take fluid. At a depth of 5300 ft., a stuffing box pressure of 2000/2300 lb., imposed on a column of mud fluid weighing 85/95 lb., was required to maintain this condition of balance.

In Burmah the producing sand lies between strata of shale, all the way from the original hand dug wells of 300 ft. to over 5000 ft. in depth. Below 5000 ft., a heavy water stratum is penetrated. With pressure drilling equipment and working against a stuffing box pressure of 800/1100 lb., a well was carried to over 7000 ft.—the deepest well in the far East.



Notice the frost on the well head fillings of this Canadian well, while high pressure naphtha gas is flowed at 75 deg. below zero.

In Burmah — returns from flow bean were passed over a suspended vibrating screen and aerated to eliminate contained gas.

From the foregoing examples of pressure drilling, extending over the past 13 years in widely separated portions of the oil world, it is evident that this method is something more than merely a recent development. In these cases, pressure drilling was only resorted to after every attempt to complete a well by other methods had failed. In many instances, complete success was not attained, but this was due rather to lack of adequate and proper equipment than to the principle employed. Complete success does not mean the ultimate completion of a well, but the ability to complete a well at reasonable cost; in a reasonable time; with the greatest safety.

Until recently, a problem arising in any one field had been handled by the personnel of that field as something entirely new to be worked out by them from the beginning. Advantage has not been taken of the experience gained in attacking similar problems in other fields, for the reason that the limited personnel experienced in such work have very often been unavailable.

Much of the pressure drilling equipment was designed on the spot to accomplish a particular purpose in some one field and, until recently, some necessary pieces have been completely lacking to handle certain phases of the work. Owing to the restricted market, engineering development has not kept pace with requirements as it has with other classes of drilling equipment.

At the present moment the picture is rapidly changing. Where in the past, pressure drilling was considered as a last resort, a method that had to be used only after every other method failed, it has now taken a definite place in drilling procedure, and indications for the future point to a continued and wider application, as the search for oil extends deeper and into more difficult formations. New equipment has been designed to take care of all phases of pressure drilling and improved to the point of efficient competition with conventional rotary methods.

Pressure drilling is the method now being used in Oklahoma by which deeper producing sands are being drilled—with oil as a circulating fluid without mudding off existing production. In some of the California fields where the original high gas pressure is rapidly falling, pressure drilling with a light drilling fluid is being tried in place of weighted mud which is sealing off production at the lower pressures.

In tight lime production in West Texas and New Mexico, where low pressure wells have been sealed off by drilling mud, pressure drilling methods have made successful completions by using oil as a circulating medium. In many instances, the hydrostatic head of even a column of light oil is greater than the bottom hole pressure of the well, and, to secure a balance between well pressures and formation pressures, the drilling fluid has been further lightened by aerating it with high pressure gas. Under these conditions, increases in production are immediately noted as the well is being drilled, and any water encountered becomes evident at once. The oil and gas used in drilling are metered into the closed pressure circuit and the returns are taken through a separator where the production is again gauged.

A wide field for pressure drilling exists where liners are set in a producing sand. With conventional rotary methods, a string of pipe is set and cemented above a producing horizon, hole is made in the producing zone and a liner set. It then becomes necessary to wash the drilling mud from behind the liner in order to secure production. A mud-cake on the walls of the hole, sufficiently strong in the first place to maintain that hole, has been further reinforced when the liner was set. The best that can be hoped for in attempting to clean away this mud-cake by washing through a screen is that a small percentage of the mudded area will be sufficiently cleaned to permit production finding its way into the hole.

With pressure drilling methods, after a string of pipe is cemented above production and still using heavy mud, a small diameter hole is cored through the producing sands to determine their character, thickness and depth. From the information obtained, a liner of screen pipe is made up and hung in the well below the stuffing box and blow-out preventer. The well is then put under pressure and the drilling mud replaced with oil as the walls of the hole are reamed to a diameter to take the liner. Pressure maintains a balance, although heavy mud has been replaced with light oil. The reamer is pulled, and with the well still under pressure, the liner is run to bottom on the drill pipe and set in a hole uncontaminated by any sealing drilling fluid. The well is ready for a production test with no further washing.

The time is coming when all wild cat wells will be equipped for pressure drilling. This does not imply that they will necessarily be drilled under pressure, but the well head will carry a stuffing box and means will be provided for rotating or running and pulling the drill pipe through it, so that at all times drilling operations can be carried on, safe from the possibility of a blow out.

In spite of all the work done to date in heaving shale, complete success as defined in this article has never been attained. It is admitted that shales of a bentonitic character swell when brought into contact with free water. Shales lying at a steep angle from the horizontal undoubtedly cave more readily than those lying flat. The most success to date in drilling the so called heaving shale has been with a collapsible bit on a string of casing, carried under continual circulation. But the nearest approach to a strictly heaving shale may be the one carrying gas.

Opening a hole in the formation by conventional rotary methods naturally creates a pressure differential and the expanding gas heaves the shale into the hole before it. With pressure drilling, a mechanical pressure is imposed on the column of weighted mud in the hole and its hydrostatic head increased until there is no pressure differential. If the collapsible bit is the solution in drilling bentonite and shales at an angle, and pressure drilling the solution with gas pressure in the formation, the combination of collapsible bit and pressure drilling may be the solution of the heaving shale problem.

Certain special equipment is required to maintain the closed pressure circuit required for pressure drilling: A stuffing box to seal the annular space between the casing and drill pipe; A back-pressure valve to prevent the well flowing through the drill pipe; Drill pipe that can be pulled through the stuffing box under pressure; A flow bean manifold through which the drilling fluid and bit cuttings are taken from well pressure to the slush pit; A round drill stem and drive bushing to rotate the drill pipe as it is fed through the stuffing box; Snubbing equipment to pull the drill pipe into the well, or control its withdrawal from the well under pressure; A hydraulic feed, to run in conjunction with this equipment, in order to permit the closest control of weights and feed to secure the greatest footage with the least number of round trips and as much freedom as possible from fishing jobs, which are undesirable under any conditions, and expensive and slow operations under pressure drilling.

Stuffing boxes or packing heads have generally been of two types: those in which the packing has been compressed by screwing down on a gland; and those in which the well pressure tightens the packing by acting directly against it. The screw type stuffing box has the disadvantage of excessive friction in the tightening mechanism. The threaded head must be of large diameter to accommodate packing of adequate cross sectional area. Tightening this type of stuffing box under high drilling pressure requires the use of

cat head and tongs;—a dangerous procedure with well head fittings under pressure. Where packing is compressed by well pressure, the pressure tightening ratio remains a constant. Greater force may be required to seal worn, leaking packing; or less force may serve while running drill pipe than is required while drilling.

An improvement over the screw type stuffing box is the one in which the packing is compressed by means of three hydraulic jacks mounted on it and a small hand pump within reach of the driller. With this arrangement, a variable compressive force, ranging from 0 to 84 tons, is imparted to the packing rings. In this stuffing box the packing is lubricated by a continual stream of water, introduced under pressure through a lantern gland between the packing rings.

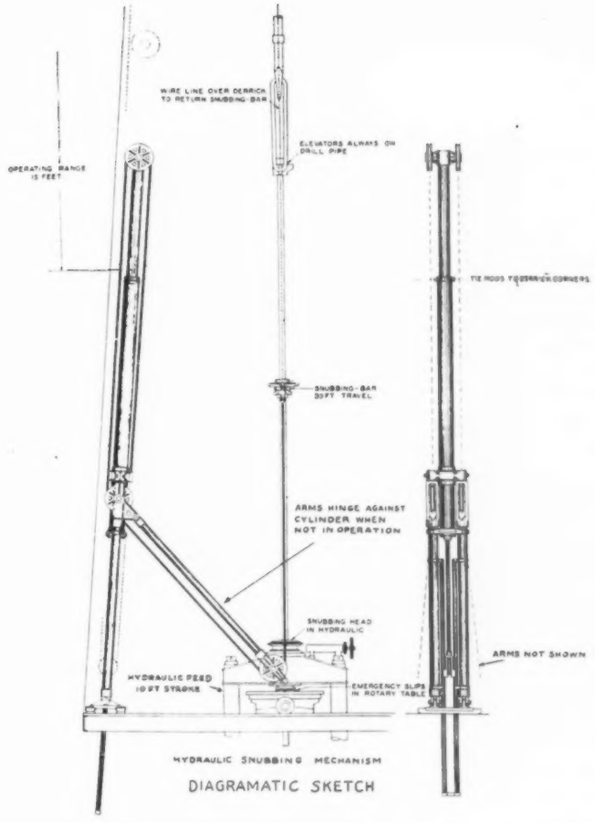
An improvement on the pressure tightening type is the one in which well pressure is used as a prime mover against a two diameter ram. Drilling fluid acting against the larger diameter of the ram transmits a superior pressure to hydraulic fluid retained behind the smaller diameter, and thus the stuffing box packing is always sealed at a greater pressure than that in the well. By varying the ratio between the two diameters of the ram, the sealing pressure ratio is varied accordingly.

Stuffing box friction on the drill pipe is a factor during snubbing operations. The drill pipe reaches the floating stage when the pressure per square inch in the well equals the weight per square inch of the cross section area of the drill pipe. Where packing can be tightened independently of the well pressure, this phase of snubbing can be shortened accordingly.

Removal of bit cuttings from a pressure well has always proved a problem. Various combinations of separators and flow beans have been made to accomplish this. It was found that existing flow beans, although serving the purpose for which they were designed—the handling of comparatively clean oil—were entirely unsuited for handling rotary drilling fluid heavily laden with sand and cuttings, and passing them from the pressure carried in the well to the atmospheric pressure of the slush pit.

The simplest bean is a nipple with a fixed orifice. It is subject to rapid enlargement through abrasion, or plugging with cuttings, and its use on a pressure well limits the pump revolutions to the narrowest range.

Beans in the form of a needle valve, while adjustable, also cut out along their length and permit nothing but the finest cuttings to pass through. For example: with a 1¾ in. orifice in which the plunger is raised 1/16 in. off its seat, no cuttings of


WIRE LINE OVER DERRICK TO RETURN SNUBBING BAR
ELEVATORS ALWAYS ON DRILL PIPE
OPERATING RANGE 15 FEET
TIE RODS TO DERRICK CORNERS
SNUBBING BAR 20FT TRAVEL
ARMS HINGE AGAINST CYLINDER WHEN NOT IN OPERATION
SNUBBING HEAD IN HYDRAULIC
ARMS NOT SHOWN
HYDRAULIC FEED 10FT STROKE
EMERGENCY SLIPS IN ROTARY TABLE
HYDRAULIC SNUBBING MECHANISM
DIAGRAMATIC SKETCH

a diameter greater than 1/16 in. can pass although an annulus with an area larger than a ⅝ in. hole is open to flow.

In pressure drilling, means must be provided to maintain a uniform back pressure on the well and at the same time recover the cuttings. If the cuttings are coarse, an opening through the bean sufficiently large to accommodate them must be provided, and the pumps run at a speed to furnish the required volume to maintain the pressure. When cuttings being recovered are fine, a slower pump speed will maintain that pressure.

In Canada, the returns were taken through a separator before being beaned to the slush pit. It was feasible in this case, as the footage made was small and the limestone cuttings, made with a hydraulic feed, were very fine. The separator was cleaned out after each run.

In India, where as much as 2300 lb. were carried on the closed circuit, separators to withstand this high pressure were not feasible and traps were constructed to remove the coarser cuttings before the drilling fluid was passed through the beans. They were made from vertical lengths of 8⅝ in. casing in which were suspended perforated lengths of 3 in. pipe. The returns entered the 8⅝ in. casing and passed to the bean manifold through the perforated 3 in. pipe. The coarse fragments of formation were retained in the annulus formed and were cleared periodically by back-flushing the traps.

Any abrasive fluid passing through a restricted orifice at high velocity produces a cutting action and fine cuttings are actually more abrasive than coarse. With these facts in mind, a bean has been designed which confines this cutting action to those portions where it will do the least damage. The returns are taken through a port of special design, shaped to permit the greatest diameter cuttings to pass through for the area opened. As this port gradually cuts out, its area is maintained by screwing a valve piston further into its sleeve. Should cuttings or caved formation plug the bean, they can be cleared quickly by screwing out the valve piston until the variable port it covers exposes an area greater than that of the pipe on which it is screwed. When closed, this bean is sealed against pressure, although the port has been partly cut out by erosion, and as all operating mechanism is on the low pressure side of the bean, there is no packing to cause trouble.

With a stuffing box carried on the well head directly below the rotary table, it has

always been a problem to turn the drill pipe as it is being fed through the stuffing box. Stuffing boxes to take square kelly, round drill pipe and tool joints have not been successful under high pressure and to drive a round kelly efficiently has been a problem. The simplest drive is a set of clamps on the drill stem, driven by two dolly bars in the rotary table; but only two or three feet of hole can be made before it becomes necessary to hitch over the clamps. A short length of hollow square kelly has been used as a drive. This clamps to the drill pipe over which it is slipped, and is turned by the rotary table. Here again the stroke is very short if the stuffing box is to be carried close to the rotary table. A drive for flush joint pipe has been made from a 35 ft. length of 8⅝ in. casing with a bushing to fit the square of the rotary table welded on the bottom, and a bushing to take a square kelly welded in the top. A square kelly driven by this bushing remains in the 8⅝ in. casing being driven by the rotary table, as the flush joint drill pipe screwed to it is being fed into the well through the stuffing box. Very bad torque conditions exist when the kelly is driven at a point 35 ft. above the rotary table, and the whole arrangement is unwieldy to place in a rathole while making connections.

A new flush joint round kelly drive has been placed on the market that employs the "free wheeling" overriding clutch principle. This drive bushing fits the square of the rotary table in place of the regular square "kelly" drive bushing. The drilling torque is transmitted directly from the rotary table to the drill pipe through a series of ten cam segments having over 100 square inches of serrated driving area in contact with the drill pipe. This large driving area permits the pipe being turned without marking it sufficiently to interfere with the stuffing box seal.

When small diameter drill pipe is being used at depth and the bit is stopped by some obstruction at the bottom of the hole, considerable twist is imparted to the pipe before the rotary table is stopped. Where a regular kelly is being used and the clutch thrown out, the backtwist in the pipe spins the table in the reverse direction. The inertia of the heavy rotating parts acting as a fly-wheel carries the drill pipe past the point of twist and may very easily result in unscrewing it. The drive bushing using the overriding clutch principle does not grip the drill pipe in the reverse direction of rotation but is freed from it as soon as any backtwist has been eliminated.

Square drill stems have reached the limit of length to which they can be made and transported and they cannot be made sectional, owing to the difficulty of making a tight joint between sections and at the same time have the two squares coincide. A flush joint round kelly can be screwed to a tight joint and used with this drive bushing; a stand at a time could be drilled with a jointed kelly long enough to permit it.

In running or pulling drill pipe against pressure, three phases must be considered: The light phase, when the drill pipe is lighter than the well pressure and therefore must be snubbed; the floating phase, when the drill pipe is in the transition stage, its weight equal to the well pressure; and the heavy phase, when the drill pipe, per square inch of cross section area, is heavier than the well pressure per square inch. Each phase is further divided into two operations: moving, when the drill pipe is being snubbed or run on the elevators; and stationary, when the drill pipe is being held either with a snubbing head or the pipe slips, while the snubbing bar or elevators are returned.

The snubbing cycle is considerably more complicated than it would appear from a casual consideration. With the drill pipe run and pulled, either with or without a hydraulic feed, four variations of three phases divided into two operations compose the snubbing cycle; and twenty-four possible operations must be considered, and their safe execution provided for, should a sudden change of well pressure occur at any time.

The simplest arrangement for snubbing is a cable attached to the two ends of the snubbing bar, passed under two sheaves fixed at the rotary table and the loop over the hook on the traveling blocks. The snubbing is done with the draw works. Hoisting pulls the pipe into the well against pressure, or the well pressure forces the pipe out of the hole to be braked with the drum. Two objects cannot occupy the same space at the same time, yet traveling blocks are hung on the center line of the derrick and the drill pipe is run in the center of the well, and they must pass each other if more than a single is to be snubbed from the hole. With the traveling blocks used for snubbing, the elevators are not available for racking pipe or placing stands to be run, and the cat line has to be used to return the snubbing bar to the top of its stroke.

An improvement over the draw works is a hydraulic snubbing mechanism in which the snubbing bar is attached to two piston rods which operate in two cylinders standing in the cellar, one on each side of the rotary table. For a 15 ft. stroke the cellar has to be 15 ft. deep or two ratholes have to be dug for the snubbing cylinders. They must be anchored to take the snubbing load and a large pump capacity is required to obtain speed in snubbing with the same pump capacity required to return the empty snubbing bar for a new stroke.

A later development in the hydraulic snubbing mechanism is a single hydraulic cylinder, standing against the side of the derrick. The cylinder contains a single acting ram, carrying a crosshead mounting two sheaves at its upper end, and a piston rod and single sheave on its lower end. Two arms extend from the snubbing mechanism to the rotary table, each of which has a sheave mounted at its outer end. A 1⅛ in. soft lay snubbing cable attached to each end of the snubbing bar passes under the sheaves at the rotary table and over the crosshead on the ram. The snubbing ram in its 15 ft. vertical travel pulls a 15 ft. loop in the snubbing cables, giving the snubbing bar a downstroke of 30 ft. When water is bled from the cylinder, the ram drops by gravity, pulling a 15 ft. loop in a ½ in. soft lay cable passed under the single sheave on the piston rod below the ram, thence over the derrick to a bridle on the snubbing bar. This movement returns the snubbing bar to the top of its stroke.

All forces in this snubbing mechanism are under compression; therefore it requires no special anchorage, and being a self contained unit, traveling blocks, elevators and draw works are left free for their own use.

While snubbing 5 in. drill pipe against 1,000 lb. well pressure, the 1⅛ in. snubbing cables have a safety factor of 9½ to 1, and a pressure of 534 lb. will be required on the ram.

There has been a great deal of confusion in associating hydraulic feed with pressure drilling. Pressure drilling is a method of rotary drilling by which the drilling fluid is maintained in a closed pressure circuit. A hydraulic, on the other hand, is a piece of machinery that is entirely independent of the well, and while it has the greatest advantage in drilling a pressure well, can be used in drilling any rotary well.

In the previous development of hydraulic rotary tables, there were certain limitations that prevented the hydraulic method of drilling from coming into general use: (1) Foundations were too elaborate and expensive to install; (2) The stroke of the hydraulic was too short to permit economical drilling in the softer formations: (3) A hydraulic table was more complicated than an ordinary rotary table; (4) Hydraulic tables occupied too much usable space under the derrick floor; (5) Drilling torque reacted on the hydraulic rams; (6) The installation of hydraulic tables required the scrapping of expensive rotary equipment, and often

structural changes in the derrick base.

Any hydraulic, to be used from top to bottom on an ordinary rotary hole, should have:—the simplest foundations, the longest stroke practicable, should take up no usable space under the derrick floor, use all existing rotary equipment, break down into units easy to transport and the drilling torque go directly from the rotary table to the drill pipe, leaving the hydraulic rams free to carry the weight of the drill pipe only.

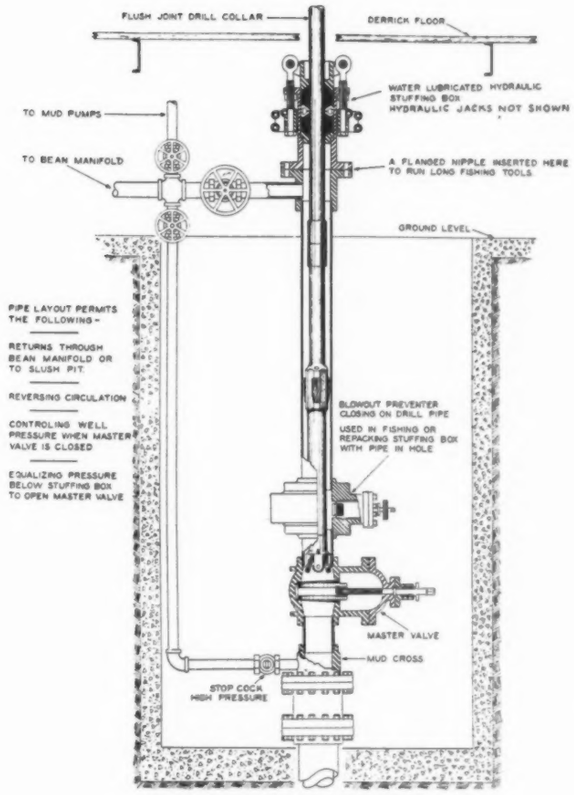
A hydraulic feed has been placed on the market, which stands on the cellar floor on foundations isolated from the derrick structure. It has a stroke of 10 ft. and operates in conjunction with regular rotary equipment, therefore blow-out preventers, stuffing boxes and well head connections occupy the same position in relation to the rotary table. There is no torque on this hydraulic and the rams carry the same drag load that is now carried on the swivel and blocks. No unit to be moved weighs over 2½ tons, although the complete assembly weighing 18 tons has a lifting capacity of 200 tons at 1,000 lb. pressure.

If a hydraulic had no other use than the control of weights and feed, it would still occupy an important place in successful pressure drilling. The present method of weight control consists of carrying a predetermined number of points on the weight indicator during the life of the bit. The actual weight on the bit may vary as much as 10 percent or 20 percent according to the accuracy of the indicator and the condition of lines, sheaves, blocks, temperature, etc., to which add 10 percent to 30 percent, depending on the skill and attention paid by the driller while feeding the bit.

Assuming that it were possible to carry the correct predetermined weight at all times with the hand feed, the following conditions would still be present at the bit; to illustrate—assume the cutting edge of a bit to be 10 in. long and dressed to a sharpness of $\frac{1}{10}$ in. (let this apply to any type of drag or roller bit). When pulled, the cutting edge has been worn until it is 1 in. thick. Assume further that 8,000 lb. is the weight to be carried. When the bit is first run it carries a load of 8,000 lb. per square inch of cutting area in contact with the formation. When pulled, the load has been reduced to 800 lb. per square inch on the 10 sq. in. then in contact with the formation. Obviously 8,000 lb. was too much or 800 lb. is too little,—one weight being ten times the other.

With 8,000 lb. on a new bit the penetration of the formation is probably greater than required for efficient cutting, and the bit is balled up or dulled out of proportion to the work it accomplishes. Likewise, the broad bearing of the 10 sq. in. in contact with the formation is better able to support a weight of 8,000 lb. per square inch. To permit working with a controlled weight at the bit, rather than with a constant weight at the surface, two accurate instruments augment the hydraulic feed: the hydraulic pressure gauge, indicating weight changes as small as 500 lb.; and the hydraulic rate-of-feed indicator, an instrument which shows a change of cutting rate as small as 1½ in. per hour.

A fast drilling rate with the lightest weight on the bit should produce fine uniform cuttings, more easily cleared by the pumps, a straighter hole with cleaner walls and the life of the bit retained at a high ratio to the work accomplished. Taking the foregoing illustration,—if the new bit is given a weight of 1,000 lb. per square inch (or 1,000 lb. total weight), the rate-of-feed indicator shows the cutting rate immediately. Increased weight may or may not increase the cutting rate, but the operator has a constant check available. As the bit becomes dulled and the area in contact with the formation increases, more total weight will be required to maintain the cutting rate, until a weight differential of 10,000 lb. will be shown on the pressure gauge if 1,000 lb. per square inch is maintained on the cutting area.


FLUSH JOINT DRILL COLLAR
DERRICK FLOOR
WATER LUBRICATED HYDRAULIC STUFFING BOX
HYDRAULIC JACKS NOT SHOWN
TO MUD PUMPS
TO BEAN MANIFOLD
A FLANGED NIPPLE INSERTED HERE TO RUN LONG FISHING TOOLS
GROUND LEVEL
PIPE LAYOUT PERMITS THE FOLLOWING -
RETURNS THROUGH BEAN MANIFOLD OR TO SLUSH PIT
REVERSING CIRCULATION
CONTROLING WELL PRESSURE WHEN MASTER VALVE IS CLOSED
EQUALIZING PRESSURE BELOW STUFFING BOX TO OPEN MASTER VALVE
BLOWOUT PREVENTER CLOSING ON DRILL PIPE
USED IN FISHING OR REPACKING STUFFING BOX WITH PIPE IN HOLE
MASTER VALVE
MUD CROSS
STOP COCK HIGH PRESSURE

WELLHEAD FITTINGS FOR PRESSURE DRILLING
TOOLS IN HOLE, STUFFING BOX IN PLACE, WELL READY TO OPEN MASTER VALVE

Before any predetermined weight can be carried on a bit, it is obvious that the total weight of the drilling string must be known accurately, because the weight carried on the bit is a portion of the total weight of the drilling string. 1,000 lb. weight is about ½ percent of an 8,000 ft. string of 4½ in. drill pipe. With the drill pipe in the hole—but with the bit off bottom—the pumps running and the table turning at drilling speed, the drilling string can be weighed accurately under all conditions applying in that particular case. A hydraulic is a scale, and just as accurate as any mechanism operated by a spring or beam. With the pressure gauge calibrated to read in thousands of pounds load on the hydraulic (instead of pounds per square inch) a direct reading is obtained.

To maintain a given weight on the bit, the bit must be advanced at exactly the same rate of speed at which it is cutting. Thus, a bit rotating at 100 R.P.M. and cutting one foot per minute, should theo-

retically be advanced $^1/_{100}$ ft. per revolution. It is obviously impossible to raise and lower the brake 100 times in the minute to accomplish this, but it is quite feasible, with a hydraulic feed, to set the bleeding valve on the manifold to maintain this rate of feed. At the same time the driller has a continual check on the advancement of the bit, merely by watching the pressure gauge hand remain in a fixed position.

If the formation remains constant, the rate of feed maintaining a given weight on the bit must also remain constant; thus the driller using a hydraulic is notified immediately of a change in formation. If the change is to a harder formation, this fixed rate of feed becomes too fast—as the advance of the bit has been slowed down—and his pressure gauge immediately notified him by dropping. On the other hand, if the formation becomes softer, his rate of feed becomes too slow for the increased rate of drilling, and he will find himself with too much weight on the hydraulic.

These changes in formation are ignored by an automatic feed, its function being to maintain a given weight on the bit, regardless of the formation being drilled. The exact depth of a change in formation is always geologically important, and very often equally important to the driller endeavoring to drill a straight hole, especially where the strata is lying at a steep angle.

It is evident that drilling is much more than an automatic operation and a hydraulic feed, rather than relieving the driller of his responsibility, becomes a source of accurate information and control, which will increase his skill.

Only the questions of weight and feed control have been touched on in this article. It is obvious that by using them, bearing wear and flat cutters will be reduced in roller type bits and increased footage will be made with all types. Core recovery will be increased and drill pipe and tool joint will have a longer life, owing to less round trips and easier use while drilling. Straighter hole and a more accurate log of formation changes will be the result.

▼

Great Britain—A Possible Oil Producer?

Portsdown No. 1 of the D'Arcy Exploration Company Spudded in March 30 with Ceremony—Speeches by Sir John Cadman and Captain Crookshank, Secretary for Mines.

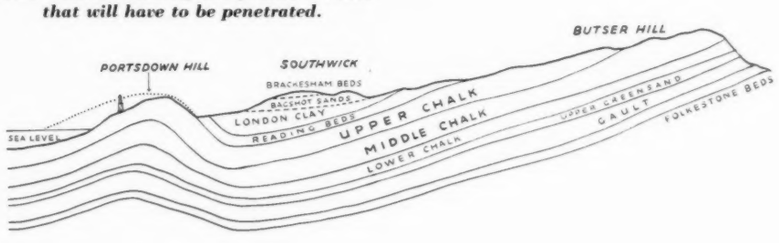
OFFICIAL inauguration of the No. 1 test well being drilled at Portsdown Hill some miles inland from Portsmouth in England took place on March 30th. The well which is the first to be drilled under the provisions of the Petroleum (Production) Act of 1934 is known as Portsdown No. 1 and is being drilled by the D'Arcy Exploration Company, Ltd., a subsidiary of the Anglo-Iranian Oil Company Ltd.

The ceremony was attended by a large number of distinguished guests, among whom were Lord Cowdray, whose grandfather drilled the first well in Great Britain for the Government between 1918 and 1922, Sir Edwin Pascoe, Director, Geological Survey of India, W. L. Mackenzie, managing director, Oil Well Engineering Company, Major H. G. Davis, Gulf Oil Corporation and many others. Sir John Cadman delivered a speech followed by an address by Captain Crookshank, Secretary for Mines. Mrs. Crookshank, mother of the Secretary, set in motion the rotary machinery.

The rig consists of a 136 ft. derrick of 400 ton capacity, a 200 ton capacity travelling block, three steam driven mud pumps capable of delivering 1500 lb. per square inch pressure and a power unit of four steam boilers with a capacity of 14,000 lb. per hour at 250 lb. per square inch pressure.

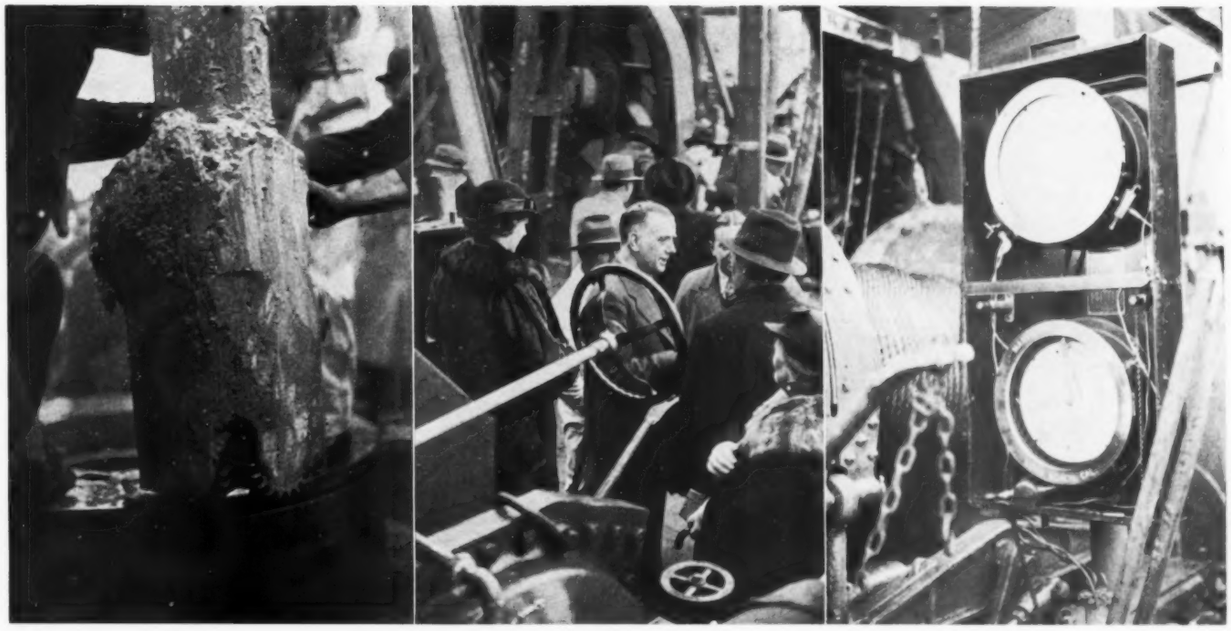
The location forms part of Government license No. 4 granted to D'Arcy Exploration along with 39 other licenses for drilling covering 6,946 square miles in Great Britain under the Petroleum (Production) Act.

Rough map of the location of Great Britain's No. 1 testwell showing the probable strata that will have to be penetrated.



"We are met to-day", said Sir John Cadman, chairman, Anglo Iranian, "to launch an enterprise which we hope will eventually be of great national importance and value. This is the first attempt to discover oil in Great Britain since the passing of the Petroleum Act of 1934. An earlier effort, which was given wartime facilities, was skilfully conducted by the late Lord Cowdray and his staff some 15 or 16 years ago. I am delighted to welcome his grandson, the present Lord Cowdray, here today. Had his lordship's grandfather been alive today, he would have been in the forefront of this venture. Unfortunately, no significant discovery was made in the areas then selected for test.

"The D'Arcy Exploration Company—a subsidiary of the Anglo-Iranian Oil Company, which is the producer of 'B.P.' petrol—has been assisted in planning its present effort by the recent advances in geological methods and drill-



Scenes at the opening ceremony for Portsdown No. 1: in the center may be seen Sir John Cadman near the drilling controls while at the right may be seen the all-important gauges to guide the driller; on the left appears a core barrel which will serve an equally important function in guiding the geologists.

ing technique. We owe much to the skilful and far-sighted manner in which the Petroleum Act of 1934 and the Regulations of 1935 were conceived and drafted, and I pay grateful tribute to the late and present Ministers, Mr. Ernest Brown and Capt. Crookshank, and to the responsible permanent officials, Sir Alfred Faulkner and Mr. Starling.

"As practical men we are setting out to puncture the skin of the earth to a depth of a mile or more, hoping to discover a stratum of rocks impregnated with that precious fluid which is responsible for so much activity in air, on land and sea. As adventurers, we are embarking on a voyage into the dim realms of the geologic past; and while our spatial progress will be prosaically logged in feet per day, in that other time-dimension we shall be regressing millions of years, like Mr. Wells's time machine, through æons of the Chalk Ocean, upon whose solidified slime we are now standing, of the Greensand Sea, and the Wealden Lake.

"In choosing this particular site we have, however, not been guided by any romantic conception of the venture. but by a volume of geological evidence. Many miles away to the east and west of where we stand there are outcrops of certain rocks of Wealden and of pre-Wealden age, which it is fair to assume lie here deeply buried below the chalk. These outcrops are in certain places heavily impregnated with petroleum. It is our hope that the drill will find these rocks porous and suitably folded to form a reservoir in which petroleum has become trapped in commercial quantities. We all appreciate the fact that the possibilities here contain a large element of speculation, but oilfields have been discovered elsewhere on no better evidence, and consequently we feel that the effort is well worth the making.

"I do not propose to embark on any explanation of the technical processes involved in drilling to such great depths as we have in mind; our guests are free to make their own inquiries, and I hope they have already done so. The outfit they see before them embodies the most modern ideas and methods, and is of British manufacture. Its rotating bit can penetrate, if necessary, to a depth of nearly three miles—as great a depth as the drill has ever reached.

"Should we be successful in our aim, we shall not be unmindful, either here or elsewhere, of doing our utmost to preserve as far as possible the amenities of the countryside of which we are all so proud.

"We are honoured today by the presence of Capt. Crookshank, the Secretary for Mines, who kindly consented to set in motion the drilling plant, thereby, we all hope, inaugurating a new industry in this country. But as I find his mother has had associations with Titusville, in the United States, where Col. Drake drilled his first oil well, I will ask Capt. Crookshank's mother to perform the task he had been going to do."

Captain Crookshank, Secretary for Mines, expressed the satisfaction of the government at finding that the Petroleum Act was considered a sound and reasonable legislation by the oil industry in Great Britain and elsewhere. He reviewed the possibilities for employment created by the present operations and by more extensive future drilling to be carried on in Great Britain and said that other applications already received for drilling permits would be granted as promptly as possible after the provisions of the Act had been complied with. Captain Crookshank also pointed out how difficult it would be for concerns that were not responsible financially and in other ways to obtain a license to drill in Great Britain.

Portsdown Hill is an anticline of Cretaceous age. The Upper Greensand and Gault and the Lower Greensand, Atherfield and Wealden are underlain by formations of Jurassic age. Palaeozoic formations are expected to be encountered between 6,000 and 7,000 ft. It is expected that drilling will occupy some time as frequent cores will be taken to establish as much information regarding sub surface formations as possible, present geology being based largely on theory in regard to the formations in that part of England.

Cementing at 8,800 ft. and 6,600 ft. in An Hour

One of the Most Interesting Recent Cementing Jobs Shows Highly Efficient Operation Possible Under Exceptionally Adverse Circumstances. Careful Preliminary Study Essential.

By C. P. Parsons

Vice President, Halliburton Oil Well Cementing Co.

WHEN WORLD PETROLEUM asked for a description of the most interesting oil well cementing job ever done, to my knowledge, it was immediately realized that the selection of any particular job out of the many thousands that have been done would involve considerable personal opinion. This would be offset to some extent by a description of the facts about the job so the reader may judge for himself.

While a number of exceptionally interesting oil well cementing jobs have been done, yet, considering all factors, there appears to be a little more activity crowded into the time involved and a few more difficult factors packed into the job done for the Texas Seaboard Oil Company and the Tidewater Oil Company in their joint operation at their Wills A-21 well at Cayuga, Texas, on July 29th, 1935.

This is the line up of conditions in the well at the time the cementing job was contemplated:

1. Approximately 8,800 ft. of 7 in. O.D. 30 lb. Grade D, long collared, casing was to be run.
2. The open hole was 8¾ inches in diameter.
3. 4,100 ft. of open hole.
4. 9 inches O.D. Casing had been set at 4,700 ft.
5. A high pressure gas sand was located in upper portion of open hole.
6. Heavy circulating fluid was required to hold down the high pressure gas.
7. There was a thirsty formation in the open hole which took ordinary mud and might take cement slurry.
8. A thick circulating mud was used to prevent loss into the thirsty formation.
9. High temperature. The temperature of the circulating mud at the overflow while drilling was 142 deg. F., which is the highest temperature known to be taken at an overflow prior to a cementing job and therefore indicated that the temperature conditions in the well were the highest ever to be encountered in a cementing job.
10. The combination of a thick, heavy drilling fluid caused a circulating pressure of 1,200 pounds while drilling.

Three three-pump steam cementing outfits in use on Willis A-21 Cayuga, Texas.

It was very desirable to place a body of cement in such manner as to protect the high pressure gas sand in the upper part of the open hole. It was also felt that due to the high temperature, high circulating pressure, tight hole, etc., that it would be very difficult to place a sufficient amount of cement behind the casing in a single stage job to cover properly the high pressure gas sand. It was therefore decided to use multiple stage cementing, placing the second stage of cement to protect the upper sand and placing the first stage of cement around the shoe to protect any productive sand which may be located at the bottom of the well.

The circulating mud was conditioned by chemical treatment before the drill pipe was pulled on the last trip before running casing. (It is very important before running casing in very deep wells to condition circulating fluid so that its gel strength and viscosity will be as low as possible to facilitate establishing circulation after the casing is run. Failures to establish circulation in several very deep wells after running casing below 9,000 feet have proven this necessity.)

The casing was 7 in. O.D. 30 lb. Grade D with long threads. It was equipped with one Howco guide shoe, two Howco float collars and one Howco multiple stage device. The float collars were installed on the first and second joints, and the multiple stage device at 6,648 ft. Circulation was established and maintained for thirty minutes before starting the cementing operation.

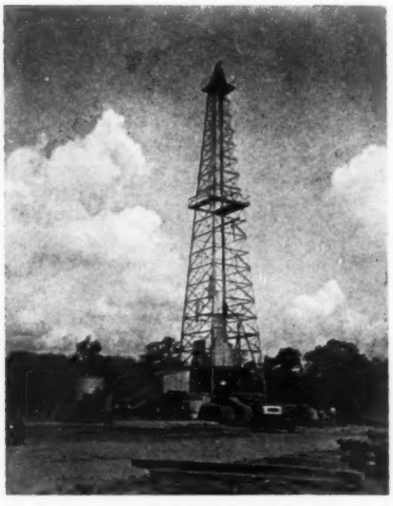
Detailed preparations for the cementing job had been carefully made in advance. The surface hook-up is shown in the accompanying illustrations. Three of the latest type three-pump steam cementing outfits were used, two of them for mixing

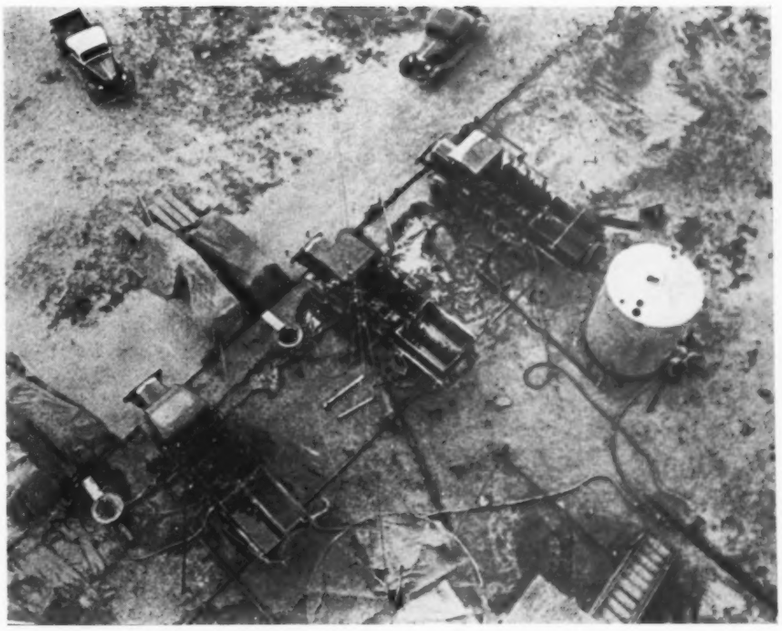
cement and the third for handling mud fluid and as a stand-by unit.

Seven hundred sacks of cement were used, 350 sacks being in the first stage and 350 in the second stage. As a result of this careful preparation only one hour and three minutes elapsed for the whole job from the time the first sack of cement was mixed until both stages of cement were landed in their respective places behind the casing.

A very interesting point is that the pump pressure never went over 1,000 lb. during the cementing operation, whereas the circulating pressure while drilling was 1,200 lb. Low pump pressure is one of the outstanding features of multiple stage cementing. A recording pressure gauge was used during the cementing operation and the chart shows that when starting to pump the first stage of cement in the casing there was a pump pressure of 1,000 lb. per square inch which gradually decreased to 250 lb. while pumping the first stage of cement into the casing. The pump pressure dropped to 100 lb. per square inch while pumping fluid between the two stages. The pump pressure increased to 500 lb. when the second stage of cement was started in the casing and decreased to almost zero pressure when fluid was pumped into the casing after the second stage. When the first stage started going around the shoe the pressure gradually built up to 850 lb., at which time the multiple stage device opened and the pressure dropped back to 250 lb. The pressure then gradually increased while placing the second stage behind the casing and reached 850 lb. when the second stage was all in place.

Cementing Willis A-21 at 6,600 ft. and at 8,800 ft. in one hour and three minutes. Picture taken during cementing operations.





Two steam cementing pumps are being used for mixing cement and the third for handling mud fluid and as a standby unit.

After the cement was allowed to set, the cement plugs, float valves in the float collars, and guide were drilled out with 2½ in. upset tubing on the bottom of which was a 5⅞ in. rock bit.

The well was then drilled to below 9,000 ft. without finding any production in commercial quantities below the 7 in. casing. It was then plugged back inside the casing to a point below the high pressure gas sand which was protected by the second stage of cement. The casing was perforated at the gas sand and the well was completed as a very large gas well, making considerable distillate. It is still producing.

Considering the physical factors involved, namely, high temperature, depth, high pressure gas, "thirsty" formations, long string of casing, tight hole behind the casing, thick and heavy mud; considering the fact that two cementing jobs were done in one continuous operation, one at 8,800 ft. and one at 6,600 ft. in a total elapsed time of only one hour and three minutes from the mixing of the first sack of cement until both jobs were completed, without any difficulty due to the physical factors encountered, this job is the most interesting to me. Considerable credit is due the officials and field men of the Texas Seaboard and Tidewater organizations for their study of every possible detail in their preparation for the job. Representing the Texas Seaboard in considering the preparations for the job were John Lovejoy, President; R. S. McFarland, Vice President; and Melbert Schwarz, Chief Petroleum Engineer; representing the Tidewater were R. B. Pringle, Vice President; Jack Ross, General Superintendent; Dal Legan, Division Superintendent; Ted Hall, Chief Petroleum Engineer; Tom Wade, District Superintendent; and George Nye, District Engineer.

▼

British Oil Imports Rise in First Quarter

FOR the first quarter of 1936 British oil imports showed an increase of 5.6 percent over the corresponding period of 1935. March, moreover, revealed a good recovery against the preceding months and March, 1935. The rise in total quantity of crude imported was again due to shipments from Iraq.

British Oil Imports by Products

(Bbl.)

	March 1936	3 months to Mar. 31 1936	3 months to Mar. 31 1935
Lamp Oil	566,655	1,563,196	1,612,139
Motor Spirit	3,622,202	8,963,998	7,939,857
Lubricating Oil	265,860	828,059	552,801
Gas Oil	346,313	824,141	966,233
Fuel Oil	1,194,112	3,827,291	4,012,885
Other Sorts	57,658	96,743	162,999
Total Products	6,052,800	16,103,428	15,246,914
Crude	959,114	3,293,286	3,120,943
Total Imports	7,011,914	19,396,714	18,367,857

Mud Treatment for Heaving Shales

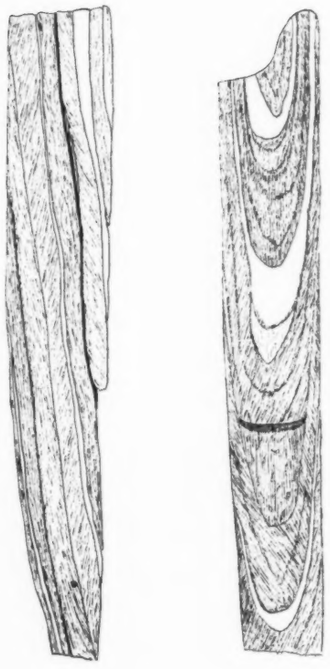
Mud Composed of Elements That Take Into Consideration the Bentonitic Character of the Shale, Prove Most Helpful in Gulf Coast Drilling.

By M. T. Halbouty

Geologist and Petroleum Engineer

ONE of the foremost drilling hazards encountered in oil and gas well drilling of today is that of heaving shales. These shales have cost operators millions of dollars in the attempt to penetrate successfully the strata in order to obtain production underneath. Heaving shales contain definite characteristics which segregate them from other shales in the geological stratigraphic column. These characteristics are both chemical and physical. The chemical characteristics of all heaving shales are singularly based upon the presence of the mineral bentonite which is a hydrous aluminum silicate and which tends to absorb water from the mud very readily. The bentonite is very important in the study of heaving shale as it is this mineral which causes the disastrous effect which eventually results in caving and slushing of the heaving shales. Of course, besides the bentonite the shale may also be classified on the basis of its other constituents, such as: arenaceous, argillaceous, siliceous, ferruginous, gypsiferous, carbonaceous, bituminous and glauconitic. Numerous studies in detail have been made on various types of heaving shales and in each case, regardless of the type; that is, whether it may be arenaceous, ferruginous, etc., the bentonite is forever present, whether in large quantities or small quantities. The shales, when studied under the microscope, reveal that between each minute layer of shale there is a small streak of bentonite in a rather pure form. In some cases the bentonite is present in streaks from one-fourth inch to one-half inch in diameter.

Figure A illustrates a core taken in heaving shale and the white streaks of bentonite in this core reach the maximum of three-eighths inch. This bentonite absorbs water from the mud so readily that the bentonite swells and causes a wedging effect. The swelling and the absorption of water is a creation of osmatic pressure which tends to increase, with the swelling, until a point is reached where the pressure becomes so great in the shale that the shale gives way towards the point of least resistance, which is the drilled hole. This condition ultimately causes the shale to heave into the hole and this may lead to disastrous effect in the sticking of the pipe or the abrupt stoppage of circulation.



Such an action, when started, is very difficult to overcome and in a few hours of continuous drilling the shale body is swelling and heaving to such a point that it is sometimes impossible to carry on with further drilling.

The physical characteristics of heaving shales are brittle, compact or sticky. The brittle shale is usually referred to in the field as "buckshot shale" because the

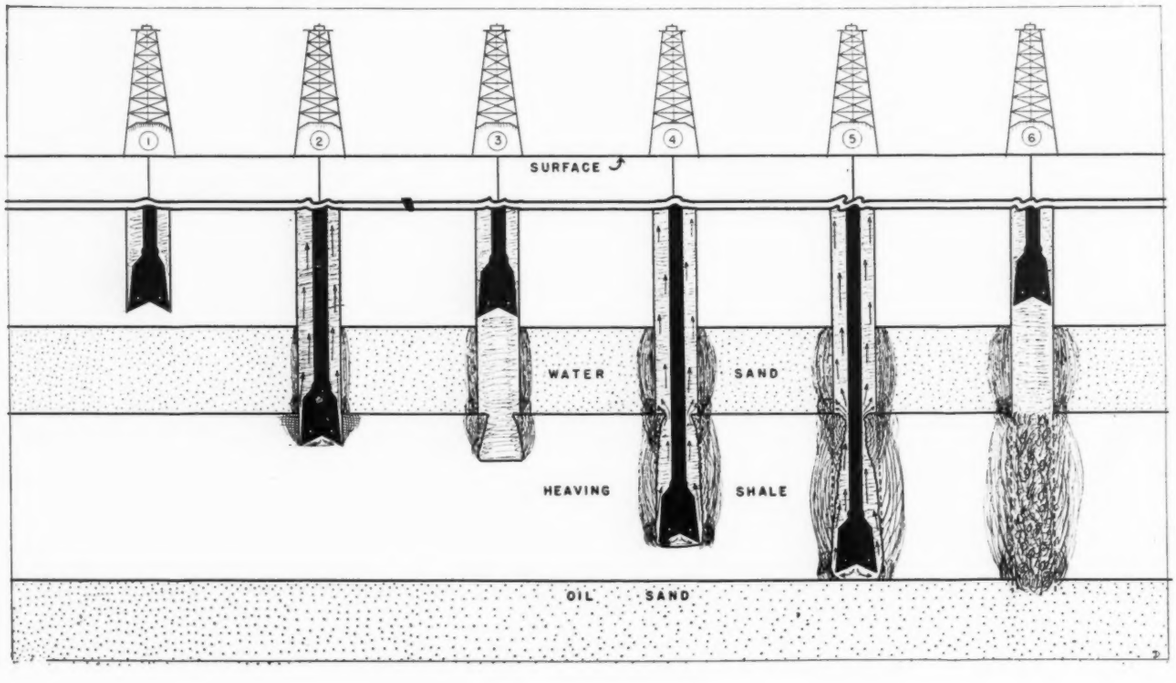


***Figure A** (above) shows long thin streaks of bentonite in a core of heaving shale.*

***Figure B** (left) is a progressive diagram showing the swelling and heaving of shale while drilling with poor muds.*

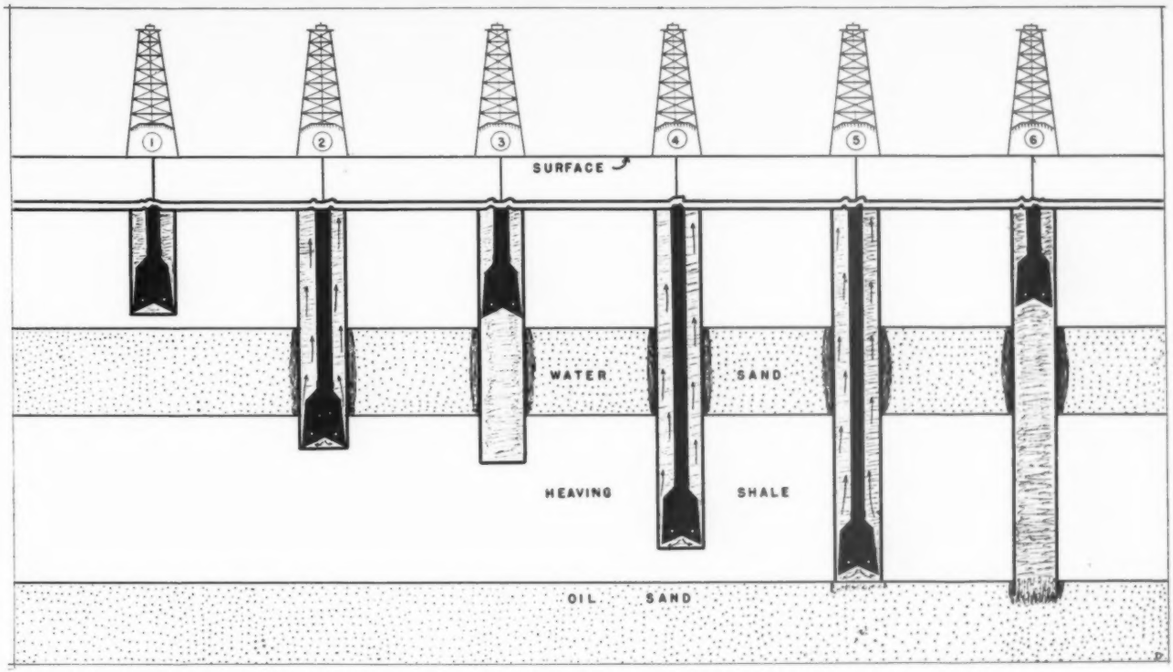


Figure C: Progressive diagrams showing penetration of heaving shales with good mud.

shale rolls out of the hole in small pieces resembling large buckshot. This shale is very difficult to combat. The brittle shale breaks down very rapidly when it comes in contact with an untreated and watery mud, as the absorption of the water from the mud penetrates the interstices of the large pieces of shale and loosens the binding effect they naturally have. This loosening causes the brittle pieces to become dislodged from their position and naturally follow the general movement of the mud upwards. This causes a leaching out of a cavity in the shale. Two things can happen when this condition is reached: First, there is no wall built around this shale, which in turn causes the mud to circulate very freely and wash out more of the shale, resulting in large cavities which in turn leaves the more resistant non-heaving shale that lies above the washed out shale unsupported. Consequently, this unsupported overlying shale will naturally slough to the bottom of the hole, sticking the pipe and causing other serious damage. In this case a non-heaving shale becomes a heaving shale in effect simply because of its lack of support. The second thing that can happen when this brittle shale is leached out is the sticking of drill pipe. The leaching usually becomes so fast that the shale is washed up in such quantities by the mud that the pumps will not handle the load, resulting in the depositing of the shale on the drill stem collars, shutting off circulation, and then sticking the drill stem. If the mud is not of such colloidal strength as to hold the shale in suspension, the pieces settle and drop over the drill collars, bit collars and bit, resulting in what drillers designate as a "balling" of the bit, and "shut off" circulation, and, in the majority of cases, stuck drill pipe. One might conclude that this type of shale heaves because of its texture and looseness, its attack by free water, mud pressure, and the turbulent flow causing leaching out of cavities and non-support of the overlying shale which really does the heaving. In such shales, a mud must be had that can build a fast, impervious wall, contain a high colloidal strength and plasticity, a mean viscosity, and an average weight. A mud which has the characteristics of a fluid while in motion and which can be handled easily by the pumps, yet one which changes to a plastic state by gelling while standing, is ideal in combating such conditions. This mud while under pressure has a low viscosity, yet is thin enough to insure rapid circulation which washes out any excess cuttings or heaving, preventing any accumulations in the hole around the bit or drill stem. At the same time, when the pumps are shut down, it becomes of such plastic nature as to prevent the settling of any cuttings around the pipe.

This type of shale contains bentonite in small quantities, however, and can not be considered as a bentonitic shale. The heaving of this type of shale is due simply to its brittle texture and the unconditioning of the mud before penetration. Nevertheless, this particular shale has caused operators more trouble than any other type of heaving shale.

The second type of heaving shale is the sticky variety which contains a large amount of bentonite. This shale causes the bit to become balled and a large amount of spudding is necessary. And, of course, the presence of bentonite adds to the difficulty in causing the shale to swell. As this shale becomes swelled and balled on the bit, necessitating a great deal of spudding, trouble will soon begin because it is this continuous spudding that causes the shale to become disturbed, breaking down all walls that have been built, consequently causing a heaving condition. Continuous spudding of a hole causes a swabbing action, which in turn produces a vacuum pressure below the swabbing point, which sucks in the already disturbed shale. Sometimes this sticky shale gradually grows in the hole because of the swelling of the bentonite, which eventually causes circulation to be stopped or the sticking of the pipe.

Figure B illustrates this particular point in this type of shale. In sub-illustration Number 1 in Figure B the bit is drilling under normal conditions without any trouble and in illustration Number 2 the bit has penetrated into the heaving shale body. The mud is probably thick and contains a high viscosity and the colloidal content is very low which in turn builds a thick and pervious wall. A large amount of free water is probably present in the fluid, as since the colloidal content is low the free water is dominant. As the wall is built next to the shale, the high absorbent strength of the bentonite in the shale absorbs the water from the mud by the process of filtration through the pervious wall. This water penetrates very deeply for several inches into the shale and begins to act on the bentonite. As the shale is first penetrated, no trouble is encountered as the process of wall building and water absorption has to take place before the shale can give any appreciable amount of trouble. More than likely, as much as 50 to 100 ft. of hole may be dug before trouble and heaving begins. In sub-illustration Number 3, Figure B, the

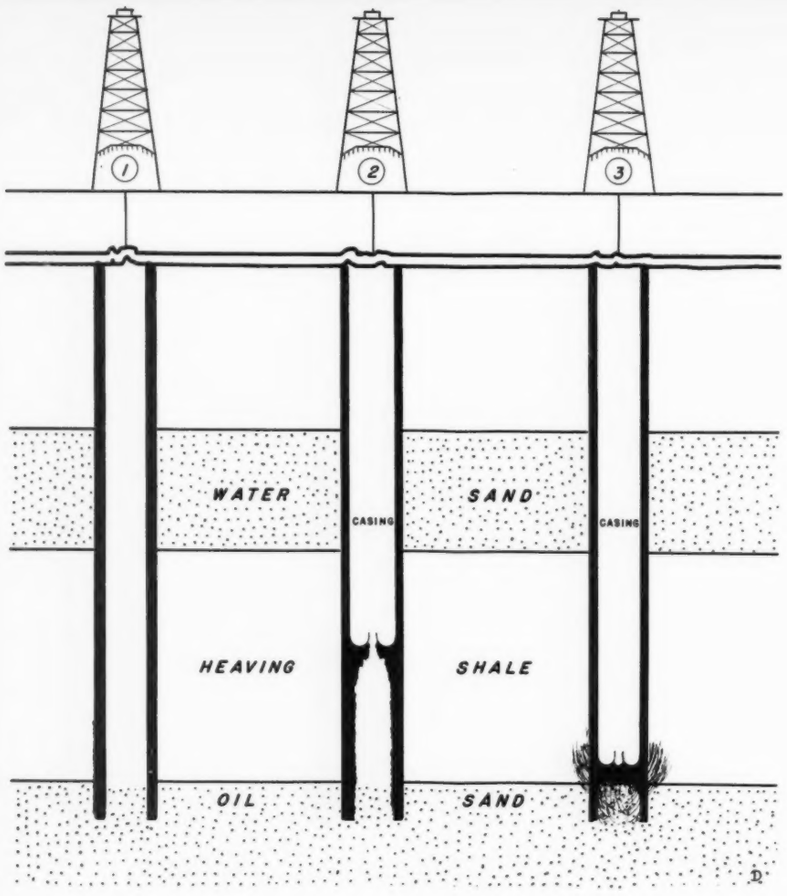


Figure D illustrates the effect of thick walls while running casing.

pipe is pulled out of the hole which gives the shale and bentonite enough time to react with the water causing a swelling and disturbance of the shale to take place. As the hole is the least resistant factor, the shale tends to swell and grow outwards to form a wedged hole with a greater opening at the bottom than at the top. The reason for the greater action of swelling at the top of the hole instead of at the bottom is because the upper portion of the heaving shale has been subjected to the poor mud longer than the lower part, and, consequently, has absorbed a greater amount of free water which, of course, causes a greater swelling and disturbance of the shale. The shale, however, at this point, has not been drilled into appreciably or absorbed enough water to heave from top to bottom and close the hole entirely, so that when the pipe is let into the hole again a slight bridge is probably encountered at the top of the shale to which no one on the job gives much thought, and without any further trouble the bridge is broken and the pipe freely seeks the bottom of the hole. Then, drilling is resumed and further penetration of the shale is attempted. As drilling is advanced with this untreated mud, the shale absorbs water and becomes sticky and the swelling is now deeper into the shale and at a greater area, as shown in sub-illustration Number 4, Figure B. In Number 5 the penetration is continued but here also the operator is having considerable trouble. The shale has probably grown and swelled very closely to the pipe which slows the pumps down considerably and causes further drilling in the shale to become extremely slow. The bit becomes balled a great deal because of lack of sufficient pump pressure and mud volume, and continuous spudding is taking place. This continuous spudding and passing of collars causes the shale above to compact against the pipe which in turn causes a swabbing effect below that point and the already disturbed shale, seeking new fields to swell and fall into, becomes like an avalanche of falling wet plaster of paris, and fills the hole either below the bit which prevents the pipe from being lowered after the pulling up for the spudding effect, or around the pipe which sticks it in the hole preventing circulation of fluid or the rotation or pulling of the pipe. If, however, the operator successfully pulls out the pipe after hair-breadth escapes, the hole around the heaving shale becomes like a solid mass of boiling stew (sub-illustration Number 6) and further penetration into this heaving and swelling hole or shale is one of great worry and tremendous expenditures. If this point is ever reached, it will pay for the operator to move over and drill a new hole. In these sub-illustrations in Figure B, one will notice that the water sand above the shale has absorbed a great deal of the mud causing the sand to become loosely consolidated. This situation in sand will sometimes cause the sand to become too loose and fall into the hole and stick the pipe. For a shale or sand of the above type, it is best to provide a mud that has such properties as, (1) to carry the cuttings up with it immediately, as in the majority of cases the cuttings will stick to the side of the hole or pipe and congregate there to such an extent as to cause serious damage, (2) a mud that builds a good thin, impervious wall, (3) has a low viscosity and (4) weight of not more than 10 pounds to the gallon unless gas is encountered in the hole and greater weight is necessary, (5) possesses a very high colloidal content and, (6) absolutely no free water. The last requirement is most important and every technique should be employed in keeping the dispersed phase (colloidal material) thoroughly mixed with the dispersion medium (water) to form true colloids.

The third type of shale is the compact type which when examined by the eye would be expected to be of such compactness and hardness as to hold itself together. In all probability this shale would give the least trouble of any of the three types. However this particular type of shale is the most bentonitic. This bentonite is really the nemesis to the three types of heaving shale and in reality causes the majority of trouble. When the mud is in poor condition this compact shale absorbs a great deal of the water and the heaving effect of this shale is the most severe of all, as the heave is very sudden and very little warning is given to the operator as compared with the other two types of shales. This shale swells within itself until the pressure becomes so great as to give way all at once into the hole causing an abrupt stop in drilling. Operators fear this compact heaving shale because of its suddenness to heave, and the pressure of its heaves is so great that oftimes it has been found to occur from 50 to 1200 ft. above its top into the drilled hole. In two instances that the writer is very familiar with, casing was set in each case to the top of the shale. Drilling was resumed and everything would be going well until this sudden heave would take place. In each case the pipe was safely drawn out of the heaving shale, but no circulation could be established in the casing after a safe distance in the pipe was held. It was necessary to continue pulling trebles out of the hole until finally, in both cases, circulation was established and later, "feeling" for bottom found the shale 1200 ft. above the bottom of the casing. Both cases were similar as both wells were drilled into the same shale body of the

same geological age. Once this shale is disturbed it is practically impossible to penetrate through it. However, if the operator would treat the mud before penetration, no trouble would be encountered. In the same area that the two wells were drilled in the illustration given above, the writer had the opportunity to come into contact with a mud that was treated 1000 ft. before the penetration of this same shale body, and which penetrated over 1100 ft. of the shale without a single heave and picked up an excellent oil sand underneath. Such a treatment saved the operator many a dollar, and the drillers on the well emphatically declared that it was not the same shale, but the positive microscope and paleontology proved it to be identically the same shale which gave trouble in two previous wells. Such a condition of treated mud and its effects can be diagnosed by following Figure C and the sub-illustrations.

In this case the shale is anticipated to be encountered at a certain depth and every precaution has been taken into consideration by the operator. Mud-pits, engineers, good pumps, chemicals, geological facts, etc., have all been checked and passed on and the drilling begins. When the hole is from 500 to 1500 ft. from the shale body, the mud is so treated from the surface casing on down that it should be in good shape for the penetration of the shale. Care of the mud from that depth on is based upon a 24-hour basis, every hour a thorough check of the mud is made insuring that no change has taken place in the physical or chemical characteristics of the fluid. In sub-illustration No. 1 Figure C, the mud is in such good shape that only a wall is built to the surface of the hole, and as the water sand is penetrated as shown in sub-illustration No. 2, a good wall is built to the sand stratum with very little mud-filtration into the sand caused solely by the high porosity of the sand, which under any normal circumstances would absorb a certain amount of the fluid. The shale is also penetrated but the wall is built very quickly and is thin and impervious. In sub-illustration No. 3, the pipe is out of the hole and the hole is just as it should be, and the shale has not been disturbed. Continuous drilling in sub-illustrations No. 4 and 5 shows that the shale is protected by a good wall and good mud, so that when the oil sand underneath the shale is encountered a trip out of the hole leaves the hole standing up and free of any heaves (sub-illustration No. 6, Figure C.)

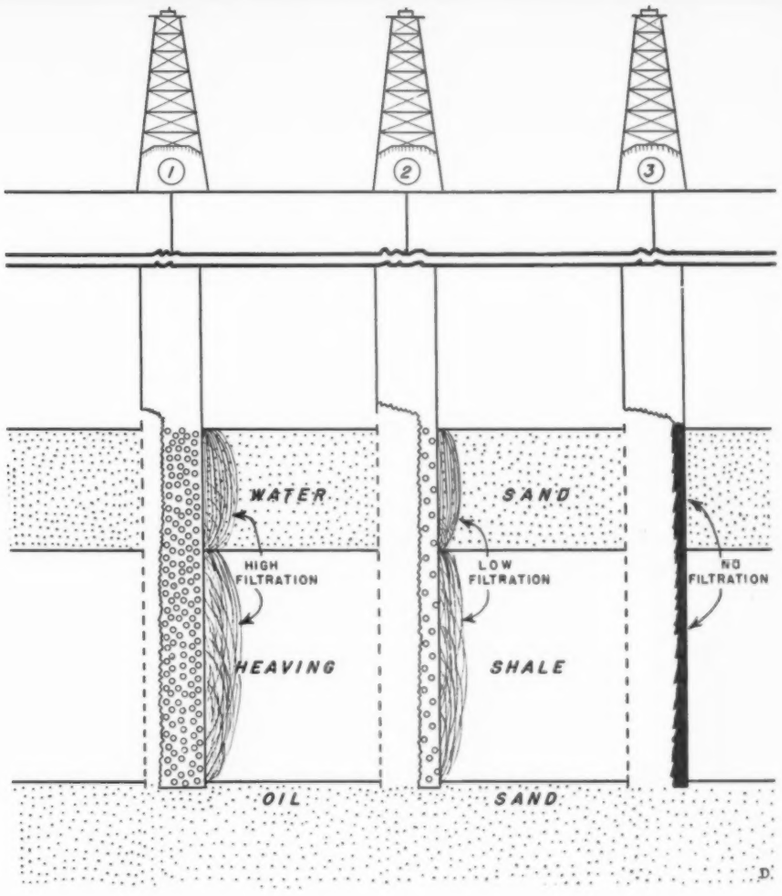


Figure E: Effect of colloidal matter on thickness and filtration medium of deposited walls.

Nevertheless, in compact heaving shale, if a heave takes place and the mud is in poor condition, it is best to pull the pipe out of the shale immediately, if possible, and pump above the heaving area. Then the mud should be thoroughly treated for the required and necessary characteristics so as to work out the heaved particles, seal off the shale and attempt to prevent the identical reaction that caused heaving. After such precaution has been taken care of, then drilling is resumed slowly so as to wall off the shale and build a good strong wall. The pump should not be opened at top speed, and the rotation of the pipe should be of a medium speed, as full force of the pump pressure at the bottom of the hole in the shale may cause an agitation in the shale before a wall can be built, and fast rotation of the pipe will slap the bit against the walls of the hole and break down walls that were being built.

One more point about the compact shale. It readily can be observed that if this shale heaves because of its bentonitic properties and the absorption of free water from the drilling mud by this mineral which causes the shale to swell and from which such an absorption is made through a poor wall condition which permits the filtration of the water into the shale, then, it is best to use a mud that has practically no free water and which can build a good impervious wall against the shale body.

It is not uncommon to find all three types of shale in one field, or area, and in one case, which the writer is familiar with, all three types of shale were found in one well. From the above diagnosis of the

TABLE 1

Field	Type	No. of Heaving Shale Wells	Greatest Penetration One Well	Total Heaving Shale in All Wells	Types of Heaving Shale
Barbers Hill, Tex.	Piercement	5	900	3,129	Brittle and Sticky
Big Hill, Jefferson City, Tex.	Piercement	1	1,123	1,123	Sticky
Double Gum Bayou, Tex.	Wildcat	1	2,363	2,363	Brittle, Sticky and Compact
Edgerly, La.	Piercement	1	1,333	1,333	Brittle and Compact
Hackberry, La.	Piercement	6	2,300	601	Brittle and Sticky
High Island, Tex.	Piercement	37	1,092	12,794	Brittle, Sticky and Compact
Hull, Tex.	Piercement	8	1,073	6,304	Brittle and Sticky
Jennings, La.	Piercement	3	902	1,708	Sticky
Sour Lake, Tex.	Piercement	2	306	569	Sticky
Spindle Top, Tex.	Piercement	7	700	1,600	Sticky
				33,286	Grand Total

three types of shale one can see that certain requisites are necessary to combat each type and these characteristics must be maintained for each type. Therefore, in this particular well, which was drilled to 9,863 ft., the mud had to contain such characteristics as to combat all three types at once. It so happened that the manner in which the types are listed above is also the manner in which they occurred in this well and it was extremely difficult to keep and maintain all of the required characteristics at one time. Nevertheless, all hazards were overcome and 9,200 ft. of 7-⅝ in. casing was successfully set through these shale bodies without any mishap. In this particular well 2,368 ft. of heaving shales were penetrated.

Often it is not the penetration of heaving shale that gives a great deal of trouble, but in order to make the job a successful penetration casing has to be run to bottom and set. Many hazards are encountered in the running of a string of casing through heaving shale, and the greatest hazard is the heaving of the shale before the casing is set on bottom and cemented. There have been numerous cases where the casing has never gotten on bottom and the fault was laid to the heaving shale where in reality the shale did not heave on its own heaving action but was forced to heave by the action of the running-in of the casing. In Figure D is a set of illustrations exemplifying this condition, and reference will be made to this figure to bring out this forced heaving action. The hole has been drilled and the shale successfully penetrated, but the mud, even though it had good qualities, had a tendency to build a thick wall (see sub-illustration No. 1), so that when the casing is being run to bottom, the wall is sheared off by the on-coming casing and builds up ahead of the guide-shoe on the casing, as shown in sub-illustration No. 2. When several hundred feet of casing have been run into this thick wall there is so much of the wall travelling ahead of the casing that the compactness becomes so great and the wall-shearing so smooth that the formation begins to fall into the hole and around the casing, as shown in sub-illustration No. 3. This prevents the casing from going any further and probably leads to sticking. In this case circulation can not be obtained because the wall is too packed against the sides of the formation and casing. It is best when the mud has thick-wall-building qualities to run in several hundred feet of casing and then stop and slowly pump and circulate the mud for a few minutes. This breaking of circulation should be maintained even to the bottom of the hole. This keeps the casing free at all times, and what wall is carried ahead of it is always pumped away.

In Figure E a portrayal of the significance of walls and their characteristics has been attempted. In sub-illustration No. 1, the wall is thick and porous and the filtration of free water from the mud is very high due to the fact that the wall lacks an appreciable amount of colloidal material. In sub-illustration No. 2 the wall is not so porous and not so thick, and the filtration is not too high but yet high enough to do damage and should be eliminated. In sub-illustration No. 3, the wall is considered ideal. The porous condition has been eliminated which in turn eliminates filtration. Such a wall is built only when the mud is highly colloidal with the correct viscosity.

Combating heaving shales has been of extreme importance in the past five years and many theories and field practices have been expounded and undertaken. Very good success has been experienced by the writer by the use of chemicals mixed in the circulating fluid to create reactions which produce a definite function while the fluid is in the hole circulating. Fifty-six different chemicals have been used to form seventy-six totally different formulas, and as many as twenty-two were used in one well alone. The chemicals were mixed for the reduction of viscosity, the liberation of gas, for building fast and thin impervious walls, for building tough impervious walls, for reacting with the shales in counteracting heaving conditions, for reduction of the salinity of muds, for decreasing or increasing the alkalinity or acidity of muds, for keeping the mud gelled while circulation is stopped, for cleaning the walls from sands underneath the shale after casing is set, for the settling out of cuttings immediately as the mud reaches the surface, for relieving stuck drill pipe when circulation is still maintained, and for many other uses which do not have any relationship to heaving shales and which will not be mentioned herein. By the use of chemicals over 33,286 feet of heaving shales were successfully penetrated under direct supervision of the writer. This figure is compiled from the amounts of shales penetrated in several fields over the Gulf Coast Area of Texas and Louisiana. The accompanying Table No. 1 will give some idea as to the extent of some shale bodies.

From the accompanying table one may conclude that heaving shales have been found only on piercement type dome. Such, however, is not the case. The wildcat drilled in the Double Gum Bayou Area, Chambers and Liberty Counties, Texas, is a non-piercement type prospect, and other companies have experienced great difficulties in non-piercement type domes. However, shales on piercement type domes are more difficult to combat than those on other types of structures. The reason can be attributed to the dip of the shale (*angle of repose*). The angle of repose is greater on piercement type domes than any other because of the enormous uplift of the formations near the salt dome. So significant is the angle of repose of shale bodies that special research was conducted on its importance for months. It is definitely known that

Table No. 2

Field	Formations Carrying Heaving Shales
Barbers Hill, Texas	Discorbis Zone, Heterostegina Zone, Marginulina Zone of Middle Oligocene Age; Vicksburg Formation of Lower Oligocene Age.
Big Hill, Jefferson City, Texas	Discorbis Zone, Heterostegina Zone, and Marginulina Zone of Middle Oligocene Age.
Double Gum Bayou, Texas	Discorbis Zone, Heterostegina Zone, and Marginulina Zone of Middle Oligocene Age; Vicksburg of Lower Oligocene Age; Whitsett of Upper Jackson Age.
Edgerly, Louisiana	Vicksburg of Lower Oligocene Age; Whitsett of Upper Jackson Age.
Hackberry, Louisiana	Discorbis Zone, Heterostegina Zone, Marginulina Zone of Middle Oligocene Age; Vicksburg of Lower Oligocene Age.
High Island, Texas	*MDe* Zone of Lower Miocene Age; Discorbis Zone and Marginulina Zone of Middle Oligocene Age; Vicksburg of Lower Oligocene Age.
Hull, Texas	McElroy of Middle Jackson Age; Caddell of Lower Jackson Age; Cockfield of Upper Yegua Age; Upper Saline Bayou of Lower Yegua Age; Lower Saline Bayou also conducive to heave.
Jennings, Louisiana	Discorbis Zone, Heterostegina Zone, Marginulina Zone of Middle Oligocene Age; Vicksburg of Lower Oligocene Age.
Sour Lake, Texas	McElroy of Middle Jackson Age; Caddell of Lower Jackson Age; Cockfield of Upper Yegua Age; Upper Saline Bayou of Lower Yegua Age.
Spindle Top, Texas	Marginulina of Middle Oligocene Age; Vicksburg of Lower Oligocene Age. The Discorbis Zone and Heterostegina Zone of Middle Oligocene Age are conducive to heave but are easily controlled by chemical treatment of the drilling fluid.

when the angle of repose is beyond the critical point (placed at from 35 to 45 deg.) the shale has a natural tendency to slough, regardless of the type, and definite mud characteristics must be had to overcome this tendency. When drilling on the flanks of domes, this factor of dip must always be constantly borne in mind by the engineer.

Various procedures have been followed by some companies in the attempt to minimize mechanically this angle of repose or dip of the shale, some believing that this angle is really the direct cause of the heave. One of the best methods, however, is to employ directional drilling. In Figure F, the illustration shows the flank of a salt dome with an oil sand underneath an overhang, but separated above and below by a stratum of heaving shale. If well No. 2 was drilled through the shale into the sand, the full dip of the shale would have to be dealt with and such a drilling would probably end in complete failure. The operator, in order to eliminate the dip of the shale, believing that this dip is causing all the trouble, drills well No. 1 away from the dome. The hole is straight to a certain depth, then it is deflected so as to encounter the shale as perpendicular as possible to the dip. If the upper stratum of heaving shale is too thick or for some other reason it is best to drill through the overhang, well No. 4 can be drilled straight to a certain depth and deflected to penetrate the overhang as well as drill through the shale perpendicularly to the dip which allows perfect penetration of the oil sand. On the other hand the operator may be fortunate enough to drill well No. 3 and go from the dome mass to the oil sand without the heaving shale bodies being encountered. Even though a well like No. 3 has been drilled, future locations and successful production may depend entirely upon directional drilling. Without a doubt, the angle of repose is a big factor in heaving shale conditions, and the writer believes that a great deal of the hazard can be eliminated by controlled directional drilling and the use of chemically treated muds. The Eastman Oil Well Survey Company have records of holes they have successfully deflected out of the salt mass to the underside of the overhang, and from outside have deflected into the under-side.

Heaving shales seem to occur in certain geologic formations more than in others, and this factor alone is of extreme importance as the geologist can easily estimate at what depth the heaving shale section may be expected. This estimate affords the operator ample time to prepare for the penetration into the shale. It is good policy to have the mud treated for the penetration from 500 to 1,000 ft. above the shale, so that when the drill encounters the shale, no serious consequences may occur. Of all the heaving shales studied and encountered in the Gulf Coast of Texas and Louisiana, the writer knows of no instance save one where heaving shales were found to exist in the Middle Oligocene Formation, or below. At High Island, Galveston County, Texas, the Lower Miocene section seems to have a high tendency to heave and does give considerable trouble, but it is believed that this section becomes troublesome because of the high angle of repose. The majority of the most difficult heaving shales are found in the Middle Oligocene section comprising the *Discorbis Zone*, *Heterostegina Zone*, and *Marginulina Zone*. The shales in these formations are highly bentonitic and all contain heaving shale characteristics. In some areas the shale is not so susceptible to heaving as in others, and still in other areas the entire shale section in the formation does not give any trouble whatsoever.

The Vicksburg formation of Lower Oligocene Age also contains a large thickness of heaving shale bodies, and so does the Whitsett, McElroy, and Caddell of Jackson Age. The Cockfield, and Upper Saline Bayou of Yegua Age, and Lower Saline Bayou of Cook Mt. Age also display a tendency to heave and in some instances the shales in these formations are very difficult to drill. Few wells in the Gulf Coast have drilled into the Cook Mountain or Mount Selman formations, and the writer knows of only several instances where heaving shales were encountered in these formations.

By using the fields listed in Table No. 1, the formations carrying heaving shales are listed correspondingly on page 272.

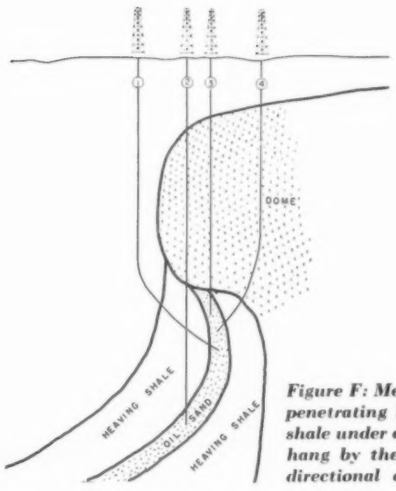


Figure F: Method of penetrating heaving shale under an overhang by the use of directional drilling.

Table No. 3 is a complete list of the geologic section from the surface to the top of the Eocene Wilcox and the formations are listed as to their mud making ability and whether or not the colloids thus formed are beneficial for the treatment of fluids in association with chemicals in fighting heaving shales.

Besides the use of chemicals, a number of companies have tried the collapsible-bit in which pipe does not have to be removed from the hole to change bits. The bit is pumped up the drill pipe by reversing circulation, or by pulling with a wire line and a new bit pumped down the drill pipe which fits snugly and accurately when it reaches the bottom of the drill collar.

Still other companies are combining chemically treated mud and especially made full-hole continuous-circulation tool joints which eliminates shutting down the pumps to make connections.

Table No. 3

Formation		Mud Making Ability	Are Colloids Helpful in Combating Heaving Shale?
Pleistocene	Beaumont	Fair	No
	Lissie	Poor	No
Pliocene	Citronelle	Fair	No
	Fleming	Good	Slightly
Miocene	Fleming	Good	Slightly
Lower Miocene	*MDc* Zone	Poor	No
Middle Oligocene	Discorbis Zone	Good	Yes
	Heterostegina Zone	Good	Yes
	Marginulina Zone	Good	Yes
Lower Oligocene	Frio	Poor	No
	Vicksburg	Very Good	Yes
Eocene: Jackson	Whitsett	Good	Yes
	McElroy	Good	Yes
	Caddell	Good	Yes
Eocene Yegua	Cockfield	Good	Yes
	Upper Saline Bayou	Good	Yes
Eocene Cook Mtn.	Crockett: Lower Saline Bayou	Good	Yes
	Sparta	Poor	No
Eocene Mt. Selman	Weches	Good	Yes
	Queen City	Poor	No
	Reklaw	Good	Yes
	Carrizo	Poor	No

Progress in Drilling Equipment

Constant Improvement in Methods and Mechanism Contribute to Real Conservation by Reducing Waste, Increasing Production and Making Available New Sources of Supply.

ALTHOUGH the art of well drilling has made great strides in the past eight decades it is still susceptible of improvement and every year new devices are brought out and advances on old methods are recorded. Today it is possible to drill a well in half the time or to twice the depth considered practicable ten or a dozen years ago.

Refinements in the use of mud and in cementing practice and better knowledge of the conservation of gas power have made it possible to avoid waste. Directional drilling and underwater drilling have made possible the opening of areas previously inaccessible. New methods of pipe perforation at depth have overcome obstacles to the flow of some wells while chemical treatment has restored others that seemed near exhaustion.

In this connection it is worth while mentioning that many—one might even say most—of the mechanical improvements in drilling and producing wells have been due to the research and experimentation of equipment manufacturers. The oil industry takes these new appliances, pays for and uses them, often with little thought to the long and expensive process of development that preceded their appearance on the market. The research and testing departments maintained by the steel companies who are manufacturers of oil country tubular goods, the makers of bits, drilling machinery, pumps, valves and specialties are among the finest and best equipped to be found anywhere. Millions of dollars go every year into the fabrication of better tools for the oil man's use and into other costly experiments that never see the light of day.

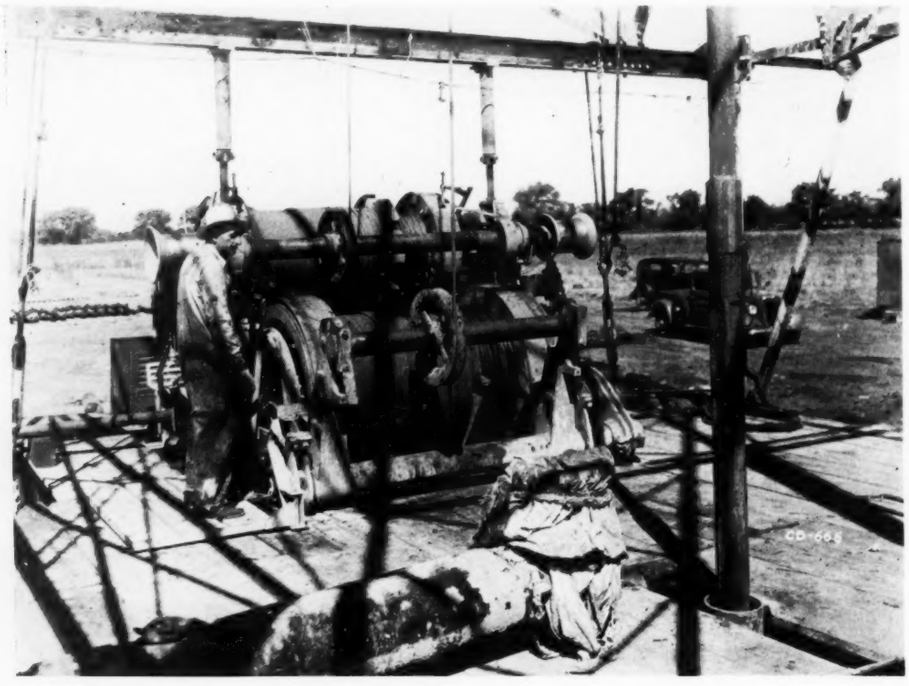
All of this work and outlay, too extensive to be enumerated here, is a most important contribution to the cause of real conservation since the net result is to make it possible to uncover oil in places formerly beyond reach and to increase the percentage of total recovery from developed fields.

In actual drilling work a combination that has come into great favor with field men in the past few years is the portable rig in which the engine and drilling equipment are mounted on a single frame and in some instances are placed in trucks or trailers with crawler-tread wheels. One of the pioneers in this field was Emsco Derrick and Equipment Co. Most of the leading manufacturers of drilling equipment are now turning out this type of mechanism which saves much of the time formerly spent in mounting, dismounting and transporting rigs. One of the most recent of these is a heavy duty spudder set on a trailer with four crawler wheels and equipped with a 150 H.P. engine mounted on the frame. It is able to handle a 5½ in. x 36 ft. stem and to drill to 4,000 ft. With shear poles the mast has a capacity of 60 tons. Three of these Star Drilling units recently were shipped for service in the Bahrein Islands.

In the design of portable rigs operated by multiple cylinder engines many improvements have been made. One of these effected by the Portable Rig Company is the complete enclosure of drive between engines, shafts, bearings and chains in a dust proof casing, a feature which contributes to the longer life of the equipment as well as to the safety of the crew. With portable units powered by two engines the power of both can be compounded through suitable transmission and clutch mechanism for such operations as hoisting the drill stem.

The question of power for drilling is discussed at some length in articles on other pages of this issue. Steam, oil and electricity all have their advantages for meeting special conditions. For field service a great increase is to be noted recently in the number of Diesel installations. For deep drilling especially the use of compounded power in the oil-electric drive has been found highly effective. One of the most effective hook-ups consists of two 300 H.P. Waukesha-Hesselman oil engines used to drive direct current generators with control that can be manipulated to throw the power of both engines into one operation or to divide it as the load demand necessitates. Elsewhere in this issue are illustrations of Atlas Imperial and other Diesel installations.

Keeping pace with the demands imposed by drilling development pump manufacturers have provided more powerful equipment for use in deep well drilling and have simplified design and operation



Model RD 6 SD double drum comet Diesel with spudder and rotary drive, manufactured by Waukesha Motor Company.

in the pumps used for ordinary operations. New designs of Gardner-Denver steam pumps handle fluid pressures up to 2,000 lb. (being shop tested to 4,000 lb.) and have capacities up to 620 gal. per minute.

Metallurgy's contributions to drilling development have resulted in increasing the strength and resisting power of casing and drill pipe while it has made possible the fabrication of bits adapted to all sorts of structure. To enumerate in detail the progress made in this field would require a volume in itself but it may be said that the provision of pipe of greater torsional resistance, stronger joints and more durable bits has made the drilling engineer's life a more enjoyable one and has contributed in no small degree to greater speed in drilling and to fewer failures and expensive fishing jobs.

Two operations that have developed into highly specialized jobs calling for the study and attention of experts are the handling of mud and cementing of the well. Cementing problems are the subject of a special article appearing elsewhere in this issue but some further observations on this subject are contributed by engineers of Baker Oil Tools Inc.

"Floating equipment is being used almost universally for running in long strings of casing. This equipment aids in the cementing of the pipe as well as providing safety and relief to surface equipment. The general practice in deep wells is to use either two float collars with a guide shoe or a float shoe and float collar. The float collars are usually placed in the first and second joints above the guide shoe in the former case and the one float collar in the first joint above the float shoe in the latter. In some cases a whirler cementing shoe is substituted for the float shoe. The distance at which the upper float collar is placed above the shoe is determined by the preference of the operator as to where he wants the plugs stopped since individual opinion varies as to the amount of cement that should be left in the casing above the shoe."

With deeper drilling higher pressures have had to be dealt with. In the Gulf Coast area of the United States relatively high pressures are frequently encountered at shallow levels and pressures ranging up to 3400 lb. are found between 6500 and 9500 ft. These higher pressures necessitate the use of blowout preventers and high pressure valves. An interesting blowout preventer hook-up providing control during drilling is manufactured by Cameron Iron Works. It consists of three pressure-operated units. On the casing is a ram-type pressure-operated blowout preventer, having no openings for flow-lines or fill-up lines, and equipped with pipe rams. Above, a second ram-type pressure-operated blow-out preventer, having two flow-line openings below the rams, is flanged. This preventer also is equipped with pipe rams. One flow-line opening is swaged to accommodate a fill-up line. The other is used as an outlet for conveying circulating fluid from the preventer to the ditch. The flow-line is equipped with a pressure-operated gate valve.

In event of a blowout, or threatened blowout, rams of the upper preventer are closed and the pressure operated flow line gate valve is closed. Circulation is then started, discharge being through a choke outlet leading from the main flow-line. While circulation is maintained, drill pipe is rotated between 15 and 30 r.p.m. and slowly raised and lowered between tool joints to prevent sticking. This is made possible by the development of self-feeding ram packing elements which automatically take up wear due to movement of drill pipe. If control of well pressures cannot be regained by increasing the weight of the circulating fluid from the point at which the bit is stopped in the hole, then drill pipe may be lubricating back to bottom with complete safety. This is accomplished by passing tool joints through the alternately opened and closed rams of the upper and lower preventers.

To permit full control on Christmas trees, valves tested to 6000 lb. are frequently needed. One of these of Hyperseal design is made of alloy steel and is used as a master control valve and for drilling through service. Another Merco-Nordstrom product for mud lines and flow lines is constructed with such ruggedness that the seven inch size weighs roundly 2,300 lbs.

A new tubing head for use in drilling or production is a development of Hercules Tool Company. Its novel feature is that it will accommodate an electric cable which passes down through the packing and slips; the packing packs off around the cable as well as the tubing.

An interesting device for separating gas from oil in the lower tubing and returning the surplus gas to the surrounding sands is the Zublin gas extractor. It takes advantage of the fact that pressure is higher in the lower part of the tubing than in the upper section and utilizes a part of this differential to operate the extractor itself while another portion is used to drive the extracted gas back into the upper part of the formation.

Another method of conserving bottom hole pressures, lowering lifting costs and reducing gas oil ratios is the G.P.I. system which accomplishes these results through use of a series of valves by which flow can be regulated and the necessity of high pressures can be eliminated.

Parkersburg heavy duty 136 ft. by 30 ft. drilling derrick mounted on a steel substructure, one of the most modern installations on the Gulf Coast.

Shooting Through Casing at 10,000 Feet

New Uses For The Gun-Perforator Are Being Developed Almost Daily and its Use is Being Extended to Canada and South America. The Ideal of Selective Production Being Realized.

COMPLETE isolation of the various oil-bearing sands in a well and their production in succession has for many years been the objective of petroleum engineers.

In the last ten years many inventions, such as electrical coring devices, formation testers and electrical "water witches" have given surprisingly accurate knowledge of subsurface conditions.

Well surveying methods, too, aided by the above developments, have improved to the point where really accurate correlation curves can be made from well to well in each field.

Cementing technique has advanced rapidly, so that now positive water shut-offs are the rule, instead of the exception.

With all these improvements in drilling methods perfected, there was—up to about four years ago—one major difficulty: An accurate and positive method of perforating casings underground, to re-open strata that had been cased and cemented off, was still lacking.

At this juncture, a Los Angeles engineering concern perfected a Gun Perforator Service. Briefly, this method consists of a cylindrical gun with a series of firing chambers, each containing a charge of powder and a sharp-nosed steel bullet. The gun is run in the well on a conductor-cable which spools from a drum on the service truck. Depth and weight indicators tell the shooter when the zone to be perforated is reached, and the pressing of an electric switch on the control panel fires the bullets, one at a time, through casings and cement and into formation, thus re-opening the designated zone to oil production.

It is of interest to note that the detonation of shots is entirely by electrical contact—no percussion is used. Due to this fact, and the use of other positive safety devices, there is not the slightest danger attending the operation.

The most common and widespread application of the gun perforator, of course, has been the well known plug-back method of bringing new life to old wells where potential producing zones had been cemented off as the well was carried down in search of deeper sands. In many fields this method has been carried out, not sporadically with individual wells, but systematically in plug-back campaigns, based on old correlation records which had been almost forgotten in oil company files.

Incidentally, the gun perforator has proved its great penetrating power in many of these old wells, where the bullets have bored through as many as three strings of casing and cement.

But a still more modern and efficient application of the gun perforator has been to anticipate future perforating needs when drilling and completing the well, and to cement a blank liner throughout the entire potential producing zone, thus isolating all water, shales and oil sands at one operation—then to perforate each oil-bearing stratum selectively, starting from the bottom zone and working up.

Another use of the gun perforator has been to improve the gas-oil ratio in wells where pressure from the oil-bearing formation has been seriously depleted. This is done by shooting one hole at a time at intervals within the suspected area, until the bottom of the formation is reached. Enough time for the gas to reach the surface is allowed between shots. When the gas is located, the operators furnish a pressure packing gland, where necessary, to control the gas pressure.

This same packing gland, incidentally, is used on all wells, such as the deep well illustrated where high pressure conditions are known or suspected. This assures complete safety while gun-perforating.

In addition to perforating for production, the gun perforator has been found applicable to various cementing operations, such as squeeze jobs for water-shut-off and cementing in stages to correct previous water shut-offs that have proved to be faulty.

Another prevalent use of the gun perforator is to perforate for final test of water shut-off after cement jobs have been performed. If the original job tests wet, the same perforations can be used for another squeeze job.

Some of the other applications found practical are: perforating clogged screens; perforating tight or clogged formations after slotted liner has been set; and perforating for acid treatment.

At present writing, gun perforator service is available in all parts of the Gulf Coast, Mid-Continent and California fields, and will be extended in the near future to the major fields in South America.

For distant points not accessible to the standard motor truck units, portable equipment on skids is being supplied. Recently a well in Alberta, Canada, was perforated with such equipment, manned by a shooter sent from the Los Angeles office.

Deepest gun perforator job to date was two miles down at Union Oil Company's famous Lillis-Welsh No. 1, Kettleman Hills, California.

World Oil Production—Official Figures for 1935 and 1936 Revised

All figures furnished direct to WORLD PETROLEUM by Governments, except where otherwise specified

(Figures in U. S. Barrels—Conversion ratio 7 bbl.=1 ton)

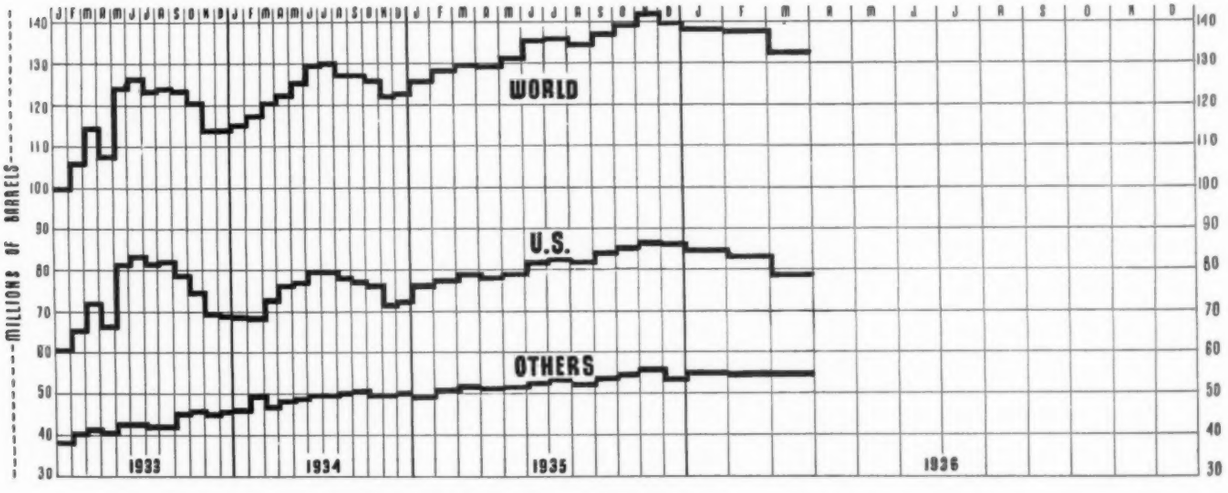
Country	April 1935	May 1935	June 1935	July 1935	August 1935	September 1935	October 1935	November 1935	December 1935	January 1936	February 1936	Provisional Figures March 1936
United States	78,427,000	82,454,000	82,338,000	85,485,000	84,816,000	84,109,000	88,160,000	86,475,000	88,711,000	88,820,000	82,120,000	80,185,721
Russia	14,092,400	15,248,800	14,232,400	14,777,000	15,091,300	14,849,100	16,040,500	16,050,000[1]	16,100,000[1]	16,500,000[1]	15,400,000[1]	15,940,000
Venezuela	11,869,900	12,175,022	13,075,118	13,429,885	12,628,067	13,151,362	13,681,619	13,152,776	13,389,789	13,487,089	12,849,480	13,432,671
Roumania	5,008,000	5,035,000	4,842,000	5,075,000	5,030,000	4,932,000	5,181,000	5,215,000	5,361,000	5,242,000	4,809,000	5,209,000
Iran[2]	4,088,000	3,927,000	4,200,000	4,249,000	4,634,000	4,270,000	4,109,000	4,522,000	4,816,000	4,627,000	4,480,000	4,641,000
Netherland India	3,438,848	3,517,360	3,463,061	3,531,857	3,699,430	3,661,259	3,767,596	3,528,889	3,612,056	3,614,436	3,407,194	3,670,877
Mexico	3,120,035	3,529,659	3,453,871	3,573,632	3,570,908	3,442,259	3,461,457	3,340,713	3,666,265	3,377,302	3,285,965	3,537,685
Iraq	1,980,174	2,034,753	1,993,586	2,445,625	2,166,794	1,962,541	2,374,393	2,309,867	2,240,819	2,327,332	2,107,210	2,515,345
Colombia[4]	1,377,299	1,486,896	1,518,460	1,639,054	1,576,307	1,555,676	1,623,372	1,582,952	1,004,474	1,611,618	1,475,403	1,619,620
Peru[5]	1,329,215	1,451,436	1,414,588	1,448,225	1,442,565	1,448,133	1,493,236	1,343,848	1,381,031	1,377,006	1,293,627	1,351,810
Argentina	1,514,968	1,203,017	1,161,638	1,198,550	1,198,537	1,152,919	1,200,698	1,193,434	1,304,554	1,195,000[1]	1,117,892[1]	1,194,988
Trinidad	899,946	953,108	972,904	988,341	1,003,382	992,445	1,015,492	1,078,957	1,086,530	1,079,082	983,424	1,081,191
British India	756,461	794,968	768,692	791,774	796,150	775,133	790,612	649,041	841,764	760,182[1]	711,138[1]	760,182
Poland	294,000	301,000	294,000	308,000	315,000	301,000	308,000	294,000	308,000	308,000	294,000	308,000
Brunei	267,603	277,550	269,290	283,430	281,400	256,480	233,310	242,900	274,540	253,400	237,930	257,250
Germany	240,464[3]	285,747[3]	257,369[3]	276,990[3]	241,801[3]	229,712[3]	232,659	236,789	263,879	254,492	227,444	274,393
Japan	167,728	154,150	144,160	146,863	152,290	144,312	158,165	145,749	147,827	183,651	165,877	170,357
Sarawak	151,067	155,400	150,850	151,830	154,000	145,600	148,400	141,400	140,700	139,300	127,050	136,290
Ecuador	145,212	147,245	137,806	144,812	135,549	138,986	147,449	143,518	146,541	148,980	139,374[1]	162,125
Canada	108,506	123,801	120,102	118,812	117,652	123,919	122,525	116,756	125,658	121,231	113,883[1]	121,489
Egypt	94,955	100,555	99,270	103,488	104,937	100,954	103,341	96,495	94,969	91,497	97,573	111,846
France	46,284	46,991	46,000	45,276	46,312	43,530[1]	44,981[1]	43,530[1]	44,981[1]	44,981[1]	42,079[1]	44,981
Others[1]	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Total	129,493,065	135,478,458	135,028,155	140,287,444	139,268,381	137,861,320	144,472,805	141,978,614	145,137,377	145,638,579	35,560,543	136,801,821

[1] Estimate. [2] Anglo-Iranian Oil Co. figures revised; fuel oil returned to the ground has been deducted. [3] Thuringia estimated 7,000 bbl.; official figure for Prussia. [4] International Petroleum Company's figures. [5] International Petroleum Company and Lobitos Oilfields Ltd. figures.

Russian Sakhalin included with Russia. Japanese Sakhalin included with Japan.

Official Crude Oil Production Figures for 1932 to 1936

Country	Total 1936	Daily Average 1936	Total 1935	Daily Average 1935	Total 1934	Daily Average 1934	Total 1933	Daily Average 1933	Total 1932	Daily Average 1932
United States	251,125,721	2,759,623	993,942,000	2,723,129	909,107,000	2,490,704	898,874,000	2,462,670	785,159,000	2,145,243
Russia	47,840,000	525,714	176,688,100	469,608	168,648,700	462,051	149,901,900	407,950	149,719,000	409,070
Venezuela	39,769,240	437,025	152,363,382	417,434	142,072,329	389,239	120,882,802	331,186	119,596,512	326,766
Roumania	15,260,000	167,692	61,150,000	167,534	62,006,000	169,879	50,971,200	139,647	50,491,205	137,954
Iran	13,748,000	151,077	52,413,879	143,600	52,663,782	144,284	49,581,280	135,840	45,122,455	123,285
Netherland India	10,692,507	117,500	42,569,625	116,629	42,289,408	115,861	38,512,663	105,516	39,584,027	108,153
Mexico	10,200,952	112,098	40,234,902	110,233	38,167,022	104,567	33,904,882	92,890	32,802,285	89,624
Iraq	6,949,887	76,372	24,850,924	68,085	7,935,657	21,742	1,200,000	3,288	1,200,000	3,300
Colombia	4,706,641	51,721	17,617,654	49,740	17,340,724	47,509	13,157,127	36,047	16,384,956	44,768
Peru	4,022,443	44,203	16,835,206	46,270	15,936,937	43,663	13,923,281	38,146	9,899,266	26,026
Argentina	3,507,880	38,548	14,317,500	39,226	14,045,652	39,015	13,759,565	38,232	13,166,900	35,975
Trinidad	3,143,697	34,546	11,669,792	31,686	10,894,363	29,847	9,560,039	26,192	10,023,780	27,387
British India	2,231,502	24,522	9,227,496	25,281	8,997,399	24,650	8,721,655	23,893	8,600,312	23,500
Poland	910,000	10,000	3,612,000	9,896	3,697,617	10,130	3,858,085	10,570	3,905,230	10,670
Brunei	748,580	8,226	3,162,614	8,647	2,673,041	7,323				
Germany	756,329	8,311	3,054,023	8,409	2,266,964	6,211	1,712,823	4,692	1,824,019	4,983
Japan	519,885	5,713	1,848,656	5,065	1,484,962	4,068	1,377,761	3,827	1,575,333	4,375
Sarawak	402,640	4,425	1,811,297	5,002	1,948,044	5,337	2,289,472	6,273	2,274,043	6,213
Ecuador	450,479	4,950	1,725,354	4,727	1,655,062	4,534	1,622,624	4,446	1,573,857	4,300
Canada	356,603	3,919	1,434,467	3,930	1,418,810	3,887	1,147,825	3,144	1,054,373	2,880
Egypt	300,916	3,307	1,215,606	3,356	1,479,037	4,052	1,591,495	4,360	1,742,370	4,760
France	132,041	1,451	529,664	1,451	552,000	1,512	552,000	1,513	552,000	1,508
Bahrein			1,264,809	3,465	285,071	781				
Others	225,000	2,473	900,000	2,470	861,000	2,359	432,000	1,184	432,000	1,180
	418,000,943	4,593,416	1,634,438,950	4,464,873	1,508,426,581	4,133,205	1,417,534,479	3,884,022	1,296,682,923	3,544,94



World crude oil production by months, 1933–1936. Chart is weighted to compensate for variation in number of days per month. Ratio of U. S. crude production to world production.

World Petroleum Abstracts

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing With Technical and Economic Aspects of the Industry. *Edited by Dr. O. W. Willcox*

Petroleum Geology

LATE RECENT HISTORY OF CÔTE BLANCHE SALT DOME, ST. MARY PARISH, LA.—Donald C. Barton, in BULL. AM. ASSOC. PETROLEUM GEOLOGISTS, vol. 20 (1936), No. 2, pp. 179–185.

One of the clearest examples of solution of the salt in the Gulf Coast is given in the late Recent history of Côte Blanche. Prior to the uplift of the present topographic mound, solution (of two salt spines?) produced two deep sink-holes, in which a great thickness of late Recent alluvium accumulated. One of the sink-holes was uplifted to form the crest of the present topographic mound and shows no effects of subsequent solution. The activity of solution under the other sink-hole continued after the uplift of the present topographic mound, possibly to the present. Formation of residual cap rock is not recognized, but is not precluded.

AGE AND CORRELATION OF SCHIST-BEARING CLASTICS, VENICE AND DEL REY FIELDS, CALIF.—Wm. H. Corey, in BULL. AMER. ASSOC. PETROLEUM GEOLOGISTS, vol. 20 (1936), No. 2, pp. 150–154.

The oil-containing, schist-bearing clastics, on the schist and below the nodular shale of the Venice and Del Rey oil fields, are determined as of Upper Miocene age by fossil mollusks found in cores. Emergence of the area in Vaqueros through Temblor into Upper Miocene time, and conformity between the schist sand and nodular shale, are indicated. They are correlated with Hoots' "basal Modelo graywacke" of Santa Monica Mountains.

PROPORTION OF ORGANIC MATTER CONVERTED INTO OIL IN THE SANTA FE SPRINGS FIELD, CALIF.—Parker D. Trask, in BULL. AM. ASSOC. PETROLEUM GEOLOGISTS, vol. 20 (1936), No. 3, pp. 245–257.

A pertinent question in connection with the problem of the origin of oil is how much of the organic content of the source beds is converted into petroleum. It is not yet possible to state definitely the proportion of the organic matter in the sediments that is transformed into oil in any particular field, but recent studies of the Santa Fe Springs field in California, in connection with investigations of source beds sponsored by the American Petroleum Institute and the United States Geological Survey, have yielded information which makes it possible to estimate the order of magnitude of the amount converted in this field.

All the oil that was in the Santa Fe Springs field at the time the field was discovered is equivalent to a yield of 0.053 percent of the weight of the prism of sediments from which the oil seems to have been derived. As the organic content of these sediments at time of deposition is calculated to be 3.0 percent of the weight of the sediments, the yield of oil would be 0.053/3.0 or 1.8 percent of the organic content of the sediments. This represents the minimum production of oil by the organic matter. The actual quantity that was generated by the source beds presumably was larger, as some oil that was formed may have failed to reach the reservoir. When the possible sources of loss of oil, such as retention by source beds, escape to the surface of the ground, destruction by bacteria, and trapping and adsorption while migrating, are considered, the conclusion is reached that the most probable yield of oil by the organic constituents is of the order of magnitude of 4 percent, though the yield may have been as high as 15 percent.

FIELD PHOTOGRAPHY FOR GEOLOGISTS.—F. T. Thwaites, in BULL. AM. ASSOC. PETROLEUM GEOLOGISTS, vol. 20 (1936), No. 2, pp. 186–214.

Many, if not most, geologists, use photography in their field work but, as they have many other duties, they can not use the heavy equipment commonly used by professional photographers. This paper presents some of the basic principles of photography, the materials commonly used in the field, apparatus adapted to the needs of geologists, and some hints on proper practice in taking photographs. Particular attention is given to the use of filters, which are essential to successful work on both distant landscapes and the details of rock exposures.

Drilling

HARDENING OF CEMENT UNDER TEMPERATURE AND PRESSURE.—S. L. Meyers, in PETROL. ENG., vol. 7 (1936), No. 7, pp. 30–31.

From the earth's surface the temperature increases with depth, the rate of increase varying with the locality. However, at depths of 6,000 ft. temperatures are met that are sufficiently high to alter the properties of hardening Portland cement-water paste. The higher temperatures stiffen the paste, making it difficult to pump; the setting times and early hardening are accelerated and the later strengths of the hardened cement are not so great as at lower temperatures.

From investigations made by the author it appears that where temperatures above 120 deg. F. are encountered, finely-ground high-lime cements are unnecessary, and perhaps even undesirable. Coarse-ground cements with a low-lime composition containing a high percentage of dicalcium silicate will give sufficient early strength at elevated temperatures; but will not be completely hydrated and therefore will have a reserve for later continuous hydration and increase of strength with time. This type of cement has the further advantage that it remains fluid longer than quick-hardening cements at high temperatures and allows more time to pump into place.

PROGRESS IN DRILLING HEAVING SHALE.—B. Mills, in OIL WEEKLY, vol. 81 (1936), No. 1, pp. 51–58.

New methods have made it possible to complete a 9,085-ft. well which passed through 2,000 ft. of heaving shale that caused the abandonment of a well near the same location. The success in this case was due to acquisition of a thorough knowledge of the causes of heaving, which are listed as:

(1) Disintegration and swelling of shale due to hydration by water from drilling muds.
(2) Aggravation of caving and heaving by inadequate or faulty mechanical methods and equipment.
(3) Action of gas blowing shale into the hole.
(4) Movement of shale caused by weight of overlying formations.

The primary cause was identified as the initial sloughing of the shale as a result of hydration and softening, and the first step in the fight against heaving was naturally to prevent hydration of the shale. As long ago as 1918 there was an application for a patent on the use of sodium silicate in drilling muds, but not until the spring of 1935 was any attempt made to use this substance for heaving-shale drilling in the Gulf Coast region.

The difference between a sodium-silicated mud and an ordinary mud is that the ordinary drilling mud, composed of colloidal matter, walls the hole by filter action; the walling material is a filter cake which lets water pass through to hydrate and disintegrate the shale, with consequent heaving and caving. With the silicated muds the walling is accomplished by a chemical precipitation of the silica in the form of alumino-silicates that seal the pores of the shale instantly against penetration by water. This quick chemical action permits rapid drilling without having to wait for the slow walling action of the ordinary muds, which are inefficient at best.

Physical and chemical control of the mud must be maintained at all times under the supervision of a chemist. During the early shale operations muds weighing 9 to 11 lbs. per gallon were used and later raised as high as 14.5 lbs., especially where gas was encountered.

However, a silicated-mud is merely the first requisite. Running the drill pipe in and out of the hole may cause destruction of the protecting coating and stimulate initial movement of the shale. It has been found that the use of heavy casing with semi-flush joints enables the drilling crew to keep the drilling string in the hole; this substitution of casing for drill pipe has been an important factor in the success thus far obtained. Most of the heaving-shale

drilling by the Continental Oil Co. is now done with a collapsible wire line bit.

A common trouble in heaving-shale drilling is the sticking of the drill stem when circulation is stopped to add to the drilling string; quick connection and continuous circulation is now provided by a "hammer joint" and the Dyer continuous circulation joint. An improved type of stuffing-box permits continuous circulation while withdrawing the wire line collapsible bit. Heavy and strong equipment, and an ample supply of spare parts are also factors of success.

Painstaking care must be taken with the mud to see that it is not diluted by rain, and that it is properly screened and de-sanded. High-pressure gas from sandy streaks may lighten the returned mud to 8.5 lbs. per gallon but de-gassing of the mud by a centrifuge is a solution of this problem.

A THEORETICAL EXAMINATION OF STRAIGHT-HOLE AND DIRECTED DRILLING TECHNIQUE.—L. V. W. Clark, in JOUR. INST. PETROLEUM TECHNOLOGISTS, vol. 22 (1936), No. 149, pp. 140–165.

From what appear to be perfectly logical premises, the author reaches some conclusions which he admits may be contested by experienced drillers. At a certain depth the drill pipe will deform spirally as a result of its length, irrespective of whether the bit is operating; this is the "critical depth." When bedding planes are tilted beyond a certain angle they will deflect the bit; this is the "critical angle." Keeping these critical factors in mind the author states the following conclusions:

In straight-hole drilling up to the critical depth, and excluding any action of the critical angle, control of the weight on the bit, of the pump pressure and the speed of rotation will definitely produce a vertical hole. The action of the critical angle of the formations will oppose the effects of these factors, and may result in the drilling of a crooked hole.

In directed drilling the control of weight, mud pressure and speed of rotation in order to cause deflection become so difficult that their effects can only be problematical. The steering of a bit by means of such factors is possible, but the exact amount of flexing or the direction in which the bit will travel cannot possibly be determined.

After the critical depth has been passed nothing that the driller can do will make the steering of the bit more definite. The instability of the string is such that the bit may travel in any direction in suitable formations, and neither whipstocks nor any other type of deflecting tool can have any effect except for the small region actually surrounding the tool. Once this region is passed the critical depth factor will once again operate.

The critical angle hypothesis has been accepted for a long period, and is dependent on the characteristics of the bit used, the angle from the horizontal at which the dip is lying, and on the relative hardness of the formation drilled through.

With a complete knowledge of these three variables, it is possible that the effect of critical angle can be overcome.

Nothing appears possible to prevent the long, thin circular shaft from deflecting when the speed of rotation reaches the critical speed. At this speed instability sets in, and, depending on the mode of vibration, so the string will assume a definite form. The center line of the shaft will never coincide with mathematical exactness with the axis of rotation owing to want of straightness, vibration, incorrect weight on the bit and other causes, and, as a result, centrifugal forces due to the inertia of the shaft will produce deflection, increased deflection resulting in increased centrifugal forces.

Oil Well Operation

CLEANING OUT PARAFFIN.—J. C. Albright, in OIL WEEKLY, vol. 80 (1936), No. 8, pp. 24–26.

Oil wells in the Wilcox sand of the Oklahoma City field are showing considerable difficulty from accumulations of paraffin, especially those wells that have lost much of their original pressure and where artificial methods are required to bring the allowable production to the top. In order to prevent this accumulation and to remove the paraffin when it does begin to form, two kinds of solvents are now generally used in this field. One of these solvents is natural gasoline, of a grade corresponding to a 26/70 product; the other is a special heavier product, with an A.P.I. gravity of about 40 deg., similar to the absorption oil used in natural gasoline plants; it has the advantage over natural gasoline of being less volatile and hence less subject to loss, and is needed in less quantity. In either case a sufficient quantity of the solvent is pumped into the well to be treated and the solvent is then "rocked" up and down in the hole by the action of the pump or gas lift. The operation has to be repeated as occasion demands, and the work is generally assigned to a special crew working over the field.

USES OF JELLY SEALS IN ACIDIZING UPPER LIMESTONE FORMATIONS.—L. G. E. Bignell, in OIL & GAS JOUR., vol. 34 (1936), No. 42, pp. 30–32.

In an oil well the following case may present itself: the well has penetrated a producing lime horizon and an underlying sand horizon which is also producing oil. It is thought that an acid treatment of the lime horizon would increase its production, but an ordinary acid treatment would have little effect on the lime because the acid would run off into the sand. This state of affairs calls for a temporary sealing of the pores of the sand, thus concentrating the action of the acid on the lime. After the lime has been sufficiently opened up by the acid, it should be possible to remove the temporary seal that was put on the sand, and restore it to production.

These objects are accomplished by a new sealing process invented by J. J. Griebe and S. M. Stosser and operated by Dowell, Inc., a subsidiary of the Dow Chemical Company. The sealing compound is introduced into the well up to the top of the porous sand and pressure is applied to force it an inch or so into the pores; it will set even where underground temperatures are from 90 deg. to more than 180 deg. F. The acidizing of the lime formation then proceeds in the usual manner, and when this operation is completed the next step is to reopen the pores of the lower sand. This is accomplished by introducing into that section of the well a culture of a certain species of bacteria which in 24 to 96 hours will destroy the organic matter composing the seal, and thus reopen the pores of the sand.

The author describes an application of this process to a well in the Edmond field where production was found in the Viola lime, below which the well had penetrated the Simpson dolomite (also producing) and had reached the productive Wilcox sand. Using the above described process, the Wilcox sand was temporarily sealed off and the lime and dolomite given an acid treatment, the results of which were quite satisfactory. The Wilcox sand was then unsealed and the well began to produce at the combined rate of 186.98 bbl. an hour instead of 40 bbl. as formerly.

The same gel may be used for testing the permeability of formations. A measured quantity of jelly seal is run in to fill the lower portion of the hole. When this has set, gas or fluid can be pumped into the hole, and if there are permeable formations above the top of the seal, the fluid will enter at a rate that can be measured. Having tested the lowest section of the formation a second batch of seal is introduced to fill up more of the lower section, and another measured gas or fluid test is made, this procedure being repeated to whatever extent may be desired.

An advantage of this method of testing is that it is made under actual formation conditions and reflects the condition of the pores around the well bore, whereas laboratory core analysis can only test small samples of the formation, and these samples may not be truly representative of the formation a short distance from the spot where taken.

PROPER CHOKING IS VITAL.—B. Mills, in OIL WEEKLY, vol. 80 (1936), No. 8, pp. 28–32.

This paper gives a review of the theory and practice of choking oil wells. "Choking" is the term used to denote the control of the rate of flow of the well by providing an opening of suitable size from which the oil may issue. The proper choice of this opening is not merely a matter of adjusting the well to give a certain production in a specified time, but has a close relation to the productive life of the well. An incorrect choke may encourage water-coning or gas channeling. In all experimental work to determine the proper choke size, the principal criteria are the gas/oil ratio, percentage of water, paraffin accumulation or fluid level. The whole matter comes down to back pressure control as the recognized means of obtaining maximum recovery efficiency. Conditions to be met are naturally variable, and the author gives an interesting account of practices followed in different fields.

NEW TYPE PNEUMATIC PUMP FOR OIL WELLS.—R. L. Chenault, in OIL AND GAS JOUR., vol. 34 (1936), No. 34, pp. 34–36.

In a new type of pneumatic pump designed by engineers of the Gulf Research and Development Corp., the subsurface equipment in the pump assembly consists of a displacement chamber with a foot valve at the lower end, a piston valve immediately above the displacement chamber, and two concentric strings of tubing. Compressed gas is supplied to the annulus between the two strings, and the flow of gas to and from the displacement chamber and to the inner string of tubing is controlled by raising and lowering the inner string, which is attached to the valve piston. The above-ground equipment consists of a lifting cylinder from which the inner tube is

suspended, a supporting stand and a timing mechanism. The action is to introduce one or more oil slugs into the inner tubing to be lifted to the surface by the gas pressure.

This pump is intended for use where gas lift equipment is available but fluid levels have dropped to a point where regular gas lift is uneconomical, and to produce by gas lift without holding back pressure on the well.

The device is considered a definite improvement over other types of displacement pumps because the capacity is higher, operation is more reliable (because the valves are positively controlled from the surface and are not likely to become sanded), there is no loss of efficiency when producing at less than maximum capacity, and it is not necessary to run intermittently for small production (the timing device may be set to produce at the required rate without starting and stopping at regular intervals). The amount of gas required is smaller than with previous types of gas lift.

Petroleum Refining

COMPUTATIONS FOR COUNTER-CURRENT SOLVENT EXTRACTION PROCESSES.—I. G. Hunter and A. W. Nash, in JOUR. INST. PETROLEUM TECHNOLOGISTS, vol. 22 (1936), No. 148, pp. 49–56.

Computations for counter-current contact processes for the extraction of a solute from a liquid by means of a second liquid have been thoroughly described in the literature. When equilibrium relationships in a complex hydrocarbon-solvent system are represented graphically on triangular co-ordinates, certain graphical computation methods may be used with fair success for this case. Although these equilibrium representation and graphical computation methods have been discussed separately in the literature, they have not so far been presented together.

This paper is therefore a brief description of a computation method suitable for application to the process of counter-current refining of petroleum products by means of selective solvents, and is essentially a survey of the author's work on this subject already published elsewhere.

REMOVAL OF HYDROGEN SULPHIDE FROM KEROSENE BY VACUUM-FLASHING.—Geo. M. Woods, in PETROL. ENG., vol. 7 (1936), No. 5, pp. 84–86.

When, as is usually the case, the kerosene fraction is obtained by direct distillation of the crude oil, it contains an appreciable amount of hydrogen sulphide, which is removed by a caustic wash ahead of the doctor sweetening operation. This caustic wash is rather expensive, as for every pound of hydrogen sulphide removed 2.35 pounds of caustic soda must be used.

As an alternative and cheaper process the author has studied removal of hydrogen from kerosene by the vacuum-flashing process. The kerosene, at ordinary temperatures, is flashed in a vacuum at 20 to 40 millimeters of mercury in an apparatus that admits of continuous operation. About 75 percent of the hydrogen sulphide can be removed in this way, while the kerosene loss from vacuum-flashing is about 0.02 to 0.05 percent, depending on the degree of vacuum. As not all the hydrogen sulphide is removed, the vacuum-flashing operation will still have to be followed by a caustic wash but the saving in caustic will be worth while where the hydrogen sulphide content is 0.4 lb. per bbl.

THE L.E.A. SOLVENT-EXTRACTION PROCESS.—Alexander Flachs, in PETROLEUM TIMES, vol. 25 (1936), No. 894, p. 282.

The author delves into history and rescues from 35 years of obscurity a solvent refining process which was a forerunner of the various solvent processes now in commercial operation.

This is the L.E.A. process which was based on the use of three solvents, ligroin, ethyl ether and ethyl alcohol. As worked out in 1900 under the direction of the late Professor C. Engler, the quantity of solvents required, in percent of oil residue treated, is approximately 75 to 100 of ether, 200 alcohol and 100 ligroin. The residue is first dissolved at ordinary temperature in the ether, and the solution is then treated with alcohol and cooled to −6 deg. F.; the cooled deposit, which contains all the paraffin wax, asphalt and pitch, is filtered and washed with cold alcohol. The filtered solution is evaporated to recover the ether and alcohol, and the precipitate is treated with ligroin (boiling point below 113 deg. F.) to separate the pitch and the wax from the asphalt. When this solution is evaporated the wax is separated from the pitch by treatment with alcohol; by distilling off the alcohol the paraffin is recovered in a pure form. The solvents all having low boiling points and low specific heats, the process is economical from the thermal standpoint. Some wide claims were made for this process at the time, but it appears that nothing came of it.

SOLVENT EXTRACTION PROCESSES.—W. R. Wiggins and F. C. Hall, in JOUR. INST. PETROLEUM TECHNOLOGISTS, vol. 22 (1936), No. 148, pp. 78–98.

The author lists the chief properties to be looked for in a commercial selective solvent for the refining of lubricating oils, as follows:

1. Chemical stability; the solvent must be stable in storage and under operating conditions, and must not react chemically with the oil processed.
2. Good selectivity; the solvent must be capable of effecting a sharp separation between the paraffinic and naphthenic constituents.
3. Adequate solvent power; the solvent should be capable of dissolving a reasonable amount of naphthenic oil. The solvent power may be increased by raising the extraction temperature, but this is only effected at the expense of selectivity.
4. The two phases formed must be capable of sharp separation, this being facilitated by a reasonable gravity differential between the solvent and stock treated.
5. The solvent should be easily and completely recoverable from the raffinate and extract phases, this being effected, in practice, by distillation.

Other properties of importance in plant design include specific heat, latent heat, vapor pressure, flash point, toxicity and corrosive power. Low specific and latent heats reduce the heat required for solvent removal. Low vapor pressure reduces evaporation loss, high flash point minimizes fire hazards, non-toxicity involves less risk to personnel, and the solvent should be non-corrosive under the conditions of operation.

The physical constants of 10 of the more prominent selective solvents are listed and flow diagrams are given for the phenol, nitrobenzene, chlorex, furfural, crotonaldehyde and due-sol processes.

CHARACTERISTICS OF SOLVENT-REFINED MOTOR OILS.—S. J. M. Auld, in JOUR. INST. PETROLEUM ENGINEERS, vol. 22 (1936), No. 148, pp. 57–77.

The success of solvent refining lubricating oils is ascribed to improvement in refinery procedure, increase in the potential sources of high-grade products, and improvement in the nature of the products. The latter is regarded as most significant, and is examined in detail in relationship to pour point, carbon forming tendency, viscosity index and resistance to oxidation and heat. On theoretical grounds it is to be anticipated that the last three would be improved by solvent treatment. Increased resistance to oxidation and thermal stability are by far the most important properties of motor oils Their behavior in motor and aircraft engines is believed to follow the course and effect of cracking procedure. It is concluded that the results of heat-oxidation tests actually run parallel to the tendency to form gum and carbon in an engine. Also that such tests will give a better interpretation of improvement in this respect the more severe are the conditions.

The effect in practice of propane-cresylic acid solvent refining on oils from particular sources and on the general standard of commercial motor oils is shown in terms of viscosity index, carbon residue and oxidation tests. Extreme paraffinicity as regards viscosity is obtainable in oils from mixed-base sources. As a means of discriminating between oils in respect to their stability, the Air Ministry test has much to commend it for general acceptance, but can be improved by raising the temperature. Measurements have been made up to 250 deg. C., and the results above 220 deg. C. are striking. The increased stability of solvent-refined oils under these severe conditions is very marked.

Mechanical tests measuring seizing temperature and variation of coefficient of friction with bearing temperature show that solvent-refined oils are, in these respects, at least as good as the best conventionally-refined oils.

In tests on a glycol-cooled engine run to simulate extreme aircraft conditions, solvent-refined oils give better results than the best ordinary high-quality oils.

Petroleum Chemistry

OXIDATION OF WHITE OILS.—Ralph W. Dornte, in IND. ENG. CHEM., vol. 28 (1936), No. 1, pp. 26–30.

The present work was undertaken to obtain data which would aid in interpreting the chemical mechanism of oil oxidation. It was found that the rate of oxygen absorption by moderately and highly refined oils can be used as a method of determining resistance to oxidation. The rate of the oxidation can be represented accurately by a simple empirical rate law. The temperature coefficient of the oxidation

reaction has been determined and shown to be an important characteristic of the oil. Certain products of the oxidation (peroxides, acids, and water) follow the same general rate law as the oxygen absorption. The results indicate that the oxidation of white oils is an autocatalytic process involving a chain mechanism whose rate determining step is preceded by a rapid dissociation equilibrium.

Determination of the Amounts of Aromatics in Commercial Gasoline.—F. Lang in PETROLEUM, vol. 33 (1936), Nos. 8 and 9.

In this paper the author makes an extensive study of literature on the composition of commercial gasolines, with special reference to methods of determination of the content of aromatics by physical and chemical methods. As a practical method he recommends treating the gasoline with concentrated sulphuric acid to remove olefines, and then determining the aromatics (benzol, toluol, xylol) by nitration with a mixture of concentrated sulphuric and nitric acids. The nitro-aromatics are then dissolved in an excess of concentrated sulphuric acid and the volume of residual gasoline, which now consists only of saturated paraffin hydrocarbons, is read off. If the original olefine-free gasoline contains more than 20 percent of aromatics it is suitably diluted with aromatic free gasoline.

Potentiometric Determination of Mercaptans.— Miroslav W. Tamele and Lloyd B. Ryland, in IND. ENG. CHEM., ANALYTIC. ED., vol. 8 (1936), No. 1, pp. 16–19.

A new procedure is described for the quantitative determination of mercaptans based on precipitation with silver nitrate. The titration is performed in an alcoholic solution of sodium acetate, using enough alcohol to dissolve the hydrocarbon sample, and titrating with a solution of silver nitrate in isopropyl alcohol. The end-point is determined potentiometrically using a silver electrode as an indicator, thus avoiding an excess of silver nitrate and eliminating the danger of simultaneously precipitating impurities.

The method is applicable to colored solutions, as the selection of the end-point is not dependent on a color change of an indicator.

Increasing the Yields in the Fischer Petroleum Synthesis.—F. Fischer and H. Pichler, in BRENNSTOFF-CHEMIE, vol. 17 (1936), No. 2, pp. 24–29.

In the Fischer synthesis a mixture of hydrogen and carbon monoxide (water gas) is passed over a catalyzer contained in a heated tube. The product is a mixture of hydrocarbons, from gases to liquids and solids, and among them considerable proportions of gasoline and lubricating oil. The yield of all products is about 70 percent of the theoretically possible.

It is now found that if the catalytic reaction is carried out in several stages the yield may be considerably increased. In the first stage the gaseous mixture is passed through the first catalyzer tube at a relatively low temperature, so that a relatively small amount of petroleum products is formed. These products are removed in a special apparatus and the residual gas is passed through a second catalyzer tube, and so on for three or more stages.

The advantage of this multi-stage process is that the concentration of the reaction mixture is kept relatively constant; it is possible to employ different kinds and amounts of catalyzers and to work at different temperatures; the process thus acquires greater flexibility. The combined yield of gaseous and liquid hydrocarbons under these circumstances is 151 grams per cubic meter of the original gaseous reaction mixture; this yield is about 80 percent of the theoretical.

Polymerization of Propylene under High Pressure and Temperature in the Presence and Absence of Phosphoric Acid.—V. N. Ipatieff and Herman Pines, before Am. Chem. Soc., Kansas City, April (1936).

The polymerization of propylene under pressure and at 330 deg. C. in the presence of phosphoric acid as a catalyst yields paraffins, olefins, cycloparaffins, cycloolefins, and aromatic hydrocarbons. The polymerization of propylene in the absence of phosphoric acid at 375 deg. C. yielded polymers containing no aromatic hydrocarbons.

The following is the composition of products formed from the thermal and catalytic polymerization of propylene.

	Thermal	Catalytic
	%	%
Paraffins	8	15
Olefins	26	63
Cycloparaffins	44	10
Cycloolefins	22	6
Aromatics	0	6

The high temperature-pressure catalytic polymerization differs greatly from the low pressure-temperature polymerization; the latter yields liquid product consisting only of open chain olefinic hydrocarbons. A method of analysis was suggested to determine the presence of the different types of hydrocarbons.

Chlorinated Paraffin.—M. B. Penn and F. T. Gardner, before Am. Chem. Soc., Kansas City, April (1936).

Chlorinated paraffin is readily dechlorinated by heating to temperatures of the order of 300 deg. C. Some properties of a series of samples obtained by dechlorination of starting materials of three different chlorine contents are presented. Chlorine elimination results in the formation of some unsaturated linkages, considerable ring closure, and in the formation of some asphaltic material. Increased initial chlorine content and increased temperature of dechlorination favor asphalt formation. Dechlorination in the presence of fuller's earth yields a low chlorine content oil of low viscosity index. Aluminum chloride accelerates dechlorination but promotes formation of asphaltic materials.

Petroleum Physics

The Measurement of Flow Rates of Hot Oil Streams by the Dilution Method.—T. A. Mangelsdorf, B. L. Sowers, and A. J. Deutser, before Am. Chem. Soc., Kansas City, April (1936).

For test purposes the dilution method of measurement is desirable for determination of rates of flow of internal recirculating hot oil streams on commercial cracking units and distillation equipment. Previously this method has not been used for oil streams because there was available no diluent which was known to be satisfactory for this purpose.

Commercial naphthenic acid produced as a by-product of the refining of naphthene base crudes has been found suitable for use in this service. Its concentration may be determined accurately even in dilute solutions with the modified method herein reported, it is sufficiently stable, it is noncorrosive, and its cost is moderate.

Rates of Solution of Gases in Oils.—E. A. Bertram and W. N. Lacey, in IND. ENG. CHEM., vol. 28 (1936), No. 3, pp. 316–318.

When the pressure within a partially depleted petroleum formation has been increased by injection of natural gas to the gas dome above the oil, there is a tendency for some of the gas to dissolve in the oil, thus lowering its viscosity, surface tension, and density. These possible favorable changes resulting from "repressuring" create interest in the rate at which the gas may be expected to dissolve under different prevailing conditions.

Previous experiments have shown that the rate of solution of a gas such as methane or propane in a quiescent body of hydrocarbon oil is controlled primarily by the rate of diffusion of the dissolved gas from the gas-oil interface into the body of the liquid. The rate for such a process is given quantitatively, up to half-saturation, by the equation:

$$Q = 2\,C_s A \sqrt{\frac{D\,t}{\pi}}$$

where Q = quantity of gas which has passed through surface
C_s = final equilibrium concentration of gas in solution
A = area of liquid, at right angles to direction of flow
D = diffusion constant
t = time

Methods of predicting, with sufficient accuracy for engineering purposes, the values of D for methane and for propane in various hydrocarbon oils have been proposed.

A study of the rate of solution of gaseous methane in hydrocarbon oils entirely filling the interstices of closely packed silica sands has shown that the process is substantially the same as for the case of quiescent oils in the absence of sand.

In the case with sands present, the over-all area at right angles to the path of diffusion must be multiplied by the fraction of the total volume of the sand body which is occupied by the oil and by a constant whose value is 0.82. The constancy of this factor has been experimentally verified only with unconsolidated sands and therefore throughout a relatively narrow range of porosites.

Electrical conductance experiments upon copper sulfate solutions held in similar sand bodies gave practically the same value of the constant, indicating that the effect of the sand is only geometrical.

High-Speed Motion Pictures of Gasoline Engine Flames.—Gerald M. Rassweiler and Lloyd Withrow, before Am. Chem. Soc., Kansas City, April (1936).

A large quartz plate mounted in the cylinder head of a gasoline engine permits an unobstructed view of the entire combustion chamber while the engine is operating. To record

the combustion phenomena occurring therein, there has been constructed a special camera which utilizes continuous film and image motion synchronized by means of thirty lenses carried in a disk mounted on the engine crank shaft. This camera photographs thirty pictures of a single explosion at rates up to 5,000 pictures per second. A pressure-time record of the same explosion is obtained. The nature of the problem was discussed, the camera described, and some moving pictures presented. These pictures show the ignition spark, the spread of the flame through the combustion chamber, the gas movements behind the flame front, and the increase in luminosity of the burned gases near the spark plug as the explosion process proceeds and the pressure rises. In addition, the flame pictures clearly illustrate the essential differences between the flame propagation in knocking and non-knocking combustion.

Physical Properties of Hydrocarbon Oils: Relations Between Molecular Weight and Concentration in Dilute Solution.—Harry T. Rall and Harold M. Smith, before Am. Chem. Soc., Kansas City, April (1936).

In determining the molecular weight of petroleum fractions by the cryoscopic or ebullioscopic methods, it is customary to determine the apparent molecular weight, m, at various concentrations and extrapolate the data to zero concentration. This paper presents data which relate the slope of the line $m = S\ C$ with the extrapolated molecular weight, M. The use of the formula thus derived will enable the calculation of M, from a single depression of the freezing point (or elevation of boiling point) of any solvent the characteristics of which have been previously determined. The formula:

$$M = \frac{KC\ M_b}{\frac{\Delta}{1 + 1.24\ C}} = \frac{m}{1 + 1.24\ C}$$

where $C = \frac{w}{W}$

is suggested for benzene (cryoscopic) and considerable data are presented to support it.

The Freezing Point and Boiling Point of Propane.—Mildred M. Hicks-Bruun and Johannes H. Bruun, before Am. Chem. Soc., Kansas City, April (1936).

A sample of pure propane has been prepared by treatment of high-grade commercial propane with chlorosulfonic acid and by subsequent fractional distillation at atmospheric pressure. The experimental value found for the freezing point of propane was −187 deg.± 0.1 deg. C., indicating that the generally accepted value for this constant is nearly three degrees too low.

Physical Properties of Hydrocarbon Oils: Behavior in Dilute Solutions of Organic Solvents. Benzene.—Harry T. Rall and Harold M. Smith, before Am. Chem. Soc., Kansas City, April (1936).

A modified Beckmann cryoscopic method for molecular weights is described. Results obtained with this apparatus using benzene as the solvent are given for oils having molecular weights of approximately 200, 300, 500, and 700. Comparative cryoscopic data from eleven cooperating laboratories for these same oils in benzene solution are given and discussed. Data are presented showing the effect of impurities in the solvent (aside from moisture), and also the effect of moisture, on determination of the cryoscopic constant and molecular weight. The presence of impurities is probably at least a partial explanation of the discrepancies universally found in cryoscopic determinations of the molecular weights of oils.

Asphalt and Tar

The Choice and Use of Bituminous Paint Materials.—H. Walther, in oel und kohle, vol. 12 (1936), No. 9, pp. 191–194.

This paper is a summary of considerations that enter into the use of asphalt, bitumen and coal tar as paint materials for roofing construction and for similar purposes. The microscopic aspect of most bitumens is that of an optically empty dark field containing mycel nuclei, which justify the conception of bitumen as a strongly protected lyophobe sol in an oil-like medium which may be different according to whether the material is a blown or a high-vacuum distilled asphalt. Coal tar is a complicated mixture of substances, and from the physical standpoint may be regarded as a colloidal dispersion of substances of high molecular weight in an oily medium; the tar resins and soot-like substances, which were formerly regarded as free carbon, are visible under the microscope as spherical globules.

All these materials have certain physical constants that characterize the mechanical resistance and the greater or smaller plasticity of their paint films. Different lots are rated by the softening point according to Kraemer-Sarnov, the breaking point according to Fraass, and the penetration by means of a needle at a certain temperature. For example, the value of a certain blown Mexican bitumen is indicated by the fact that its softening point is 65 deg. C. and its breaking point −12 deg. C., giving a spread of 77 deg., whereas a high-vacuum distilled Mexican bitumen shows a softening point of 61 deg. and a breaking point of −1 deg., thus giving a spread of only 62 deg.; in the former case the penetration at 25 deg. was 21 mm., in the other 10 mm. From these data it may be inferred that the blown bitumen will be suitable as a paint in situations exposed to marked changes in temperature or to continual vibration, whereas the principal virtue of the high-vacuum distilled bitumen will be greater resistance to the decomposing effects of light.

On the other hand, coal tar pitch is more sensitive to temperature than the asphaltic bitumens; the spread between softening and breaking points is only about 45 deg. and the penetration is practically zero. A coal tar paint is therefore sensitive to shock, although this can be improved by suitable fillers to make it nearly equal to asphalt.

The great technical advantage of these two materials is their resistance to water, although a coal tar paint will adhere somewhat better to a wet surface than an asphalt paint. For this reason very good results are obtained by mixtures of the two materials, particularly when the coal tar is used as a priming coat and the asphalt paint as the finish coat.

The author quotes some experiments tending to show that asphaltic paints are less desirable for metallic (iron) surfaces than coal tar paints, due to the greater susceptibility of the asphalt to oxidation, with formation of acid-like substances that corrode the metal; in this respect the high-vacuum distilled bitumens appear to be somewhat better than the blown bitumens, while nothing of the sort was noted in connection with coal tar paints.

No exact information is at hand to indicate the value of watery bitumen or tar emulsions for paint purposes, but exaggerated expectations in this direction do not appear to be warranted.

Viscosity Temperature Susceptibility Coefficient as an Index of the Effect of Temperature on the Consistency of Asphalts.—H. G. Nevitt and L. C. Krchna, before Am. Chem. Soc., Kansas City, April (1936).

Inasmuch as the absolute measure of consistency is viscosity, the authors point out that the change of consistency of an asphalt with temperature would be more logically measured as the change of viscosity with temperature. The objections to the usual empirical susceptibility indices are discussed and the requirements of a satisfactory index outlined. The viscosity-temperature susceptibility coefficient (V.T.S.) is presented as a more fundamental viscosity-temperature index based on the A.S.T.M. viscosity-temperature formula and mathematically represented as

$$S = 0.221\ \frac{\text{Log}\ \frac{\text{Log}\ (V_1+0.8)}{\text{Log}\ (V_2+0.8)}}{\text{Log}\ \frac{T_2}{T_1}}$$

where S is the V.T.S., V_1 and V_2 the absolute viscosities at specified absolute temperatures T_1 and T_2. Graphically S would be the slope of a straight line connecting the two points obtained by plotting on the A.S.T.M. Chart D–341–32T the viscosities of an asphalt as obtained at two temperatures. Data presented indicate that the V.T.S. is applicable to a wide range of temperatures, consistencies and viscosities, whereas the empirical indices are limited to definite temperatures and relatively narrow ranges of consistency.

Use of Petroleum

Chlorine Compounds Added to Lubricants: Chemical Constitution and Timken Film Strength.—Bert H. Lincoln, Gordon D. Byrkit, and Waldo L. Steiner, before Am. Chem. Soc., Kansas City, April (1936).

The measurement of the Timken film strength of an oil containing a chlorine bearing organic compound is of value in the preliminary selection of addition agents for use in lubricating oil. The film strength by this method is only one of many factors which must be considered in the choice. Actual service tests must determine the final selection of an addition agent. By carefully controlling the conditions of the test and by expressing the results in terms of

the Timken Index which is here developed, the effect of different molecular structures on the ability to improve the Timken film strength is compared.

ALTERATION OF LUBRICATING OILS IN USE AND THEIR REGENERATION (Zur Frage der Veranderung von Schmierolen in Gebrauch und ihrer Regenerierung).—H. Kamftner, published 1935, by Austrian Petroleum Institute, Vienna.

This work contains a very extensive critical review of the literature on the alteration of lubricating oils during use, and their regeneration. In addition, the author has carried out some strictly controlled road tests with selected oils and extensively discusses the results. The work will be of interest to oil technologists interested in the regeneration of used oils.

TESTS OF HIGH FILM STRENGTH MOTOR OIL.—T. C. Delbridge, announcement by the Atlantic Refining Co., 1936.

The Atlantic Refining Co. reports the creation of an "alloy oil" which will stand 15,000 pounds pressure per square inch, which is three times normal. In order to demonstrate its performance a five-months road test was made in which six stock automobiles, two Chevrolets, two Fords and two Plymouths, were driven continuously over an 80 mile circuit including open roads, traffic through towns, a railroad crossing, rolling hills, traffic circles and normal travel arising from a week-end peak. The drivers, who worked in shifts, were of assorted ages and professions. The cars were kept continuously in motion, six days a week, during which time they were given ordinary maintenance and lubrication service. The test was continued until all cars had run 100,000 miles each. Three of the cars required no repairs of any kind during the test, two required new cylinder heads because of cracked water jackets and new propeller shafts on account of mechanical failure. One required a new wheel ball bearing because of scoring due to road sand; two required valve grinding after 50,000 miles. No crank case was removed from any car, nor was any maintenance given to cylinder wall, piston, piston ring, connecting rod bearing or main bearing. Oil consumption, one quart per 565 miles; gasoline consumption, 20.9 miles per gallon. Average cylinder wear, 0.0007 inch; average piston ring gap increase, 0.012 inch.

The lubricating oil used in this test is a mineral oil produced by the company, to which is added one percent of a chlorinated ester of phosphoric acid. This addition increases the film strength, or ability to withstand pressure, by the astonishing amount of 200 percent.

PROPANE, THE PERFECT FUEL.—A. Ludlow Clayden, before Am. Chem. Soc., Kansas City, April (1936).

It is believed that propane is an ideal fuel for an I.C. engine because it stands very high compression, thereby giving good thermal efficiency; because it is perfectly clean burning, leaving no combustion chamber deposits; because it can be distributed perfectly through a manifold, which is not true of any wet gas. Also if high power for weight of engine is very important, this should be attainable to a degree beyond that possible with any other fuels.

Recently a test was run on a C.F.R. engine on propane at a series of compression ratios taking indicator diagrams. Also power readings, comparing the output from the same C.F.R. engine with propane and gasoline. In cooperation with Jehle of the White Motor Co. tests have been run on a truck motor with different compressions, and this work checks pretty well with the C.F.R.

The paper reviews these tests and discusses some of the special problems of designing equipment for propane and some of the subsidiary advantages and drawbacks. The fact that the exhaust is odorless is one very important thing for some applications; the fact that the fuel can be used as a refrigerant is another.

Petroleum Substitutes

METHYL ALCOHOL IN MOTOR FUELS.—K. R. Dietrich and W. Lohrengel, in OEL UND KOHLE, vol. 12 (1936), No. 5, pp. 91–92.

The recent German decree requiring the admixture of 10 percent of methanol with ethyl alcohol for fuel purposes, and the compulsory use of 10 parts of this mixture with 90 parts of cracked gasoline has caused a little trouble to motor engine builders. Methanol corrodes the light aluminium-zinc-magnesium alloys, forming magnesium methylate; this action is more pronounced in a gasoline mixture than in the pure methanol. Iron and lead-coated iron are attacked, and even galvanized iron is stripped of its coating of zinc. The question of just what changes must be made in the composition of metal alloys used by the engine builders still awaits completion of further investigations.

SO-CALLED COLLOIDAL FUELS.—A. Manning and R. C. Acton Taylor, before Instn. Chem. Engineers, February 21, 1936.

The term "colloidal fuels" is applied to suspensions of finely divided carbon in a heavy fuel oil. Such fuels first became of importance during the great war, when fuel oil was not especially abundant. Some use of these fuels was made by the British Navy, but after the war the idea was allowed to drop. It was taken up again in 1932, when the oil burning ship *Scythia* made a long voyage with a liquid fuel containing 40 percent of coal in suspension. The stability of the mixture was excellent, although the burners had to be cleaned more frequently. The oil used on this voyage was a cracking residue with a carbon residue of over five percent.

In an experiment in Germany, successful use has been made of a coal tar with 45 percent of coal in suspension; the thermal efficiency was around 70 to 74 percent. It is claimed that oil mixtures with 50 percent of powdered coal that were stable for four months at the ordinary temperatures have been prepared.

The stability of these colloidal fuels is the critical point; the suspended coal must not settle out. This property may be secured by various means, as by very fine grinding of the coal or the use of stabilizers or peptizing agents; better still is the choice of a fuel oil that naturally contains stabilizing agents. The coal should be ground so fine that 80 or 90 percent will pass through a 200-mesh sieve. As a stabilizer, use may be made of 0.1 to 1 percent of soap and heating the oil to 200 deg. C.; various other stabilizers, such as old rubber, wax, alkaline salts, etc. have been proposed. Heating the oil to stabilize the mixture should be avoided where possible as this operation adds to the expense.

As regards the economics of the proposition, the colloidal fuel will generally cost less than fuel oil alone at current prices, unless the method of stabilization employed is expensive; hence oils that naturally contain stabilizing constituents will be preferred. For marine use the colloidal fuel has two points in its favor; the first is that per unit of volume the colloidal fuel has a higher calorific value than plain fuel oil. This is evident from the following table:

Fuel	Calories
Coal alone	6,400
Fuel oil alone	9,500
Colloidal fuel	9,900

The above figures are for a mixture of coal having a calorific value of 8,055 cal. and an oil with a calorific value of 10,550 cal., mixed in the proportion of 40 pounds coal to 60 pounds oil. The special advantage of this mixture for marine use is that it has a higher density (1.04) than oil alone, and hence there is a saving in bunker space.

In a larger social-economic view the matter is of interest as offering a means of easing the competition between the coal mining and the petroleum industries in so far as relates to heavy oil fuels.

OLIVE OIL AS A LUBRICANT.—Anon., in COURIER DES PETROLES, vol. 17 (1936), No. 694, pp. 1–2.

Following the line of action which is designed to benefit agriculture by all possible means, the French parliament has taken up a proposed law to make obligatory the admixture of a certain proportion of olive oil with all lubricating oils; the proportion specified is 20 percent. As the average annual lubricating oil consumption (excluding reclaimed oil) is about 250,000 tons, this law would create a market for 50,000 tons of olive oil, which is greater than the quantity now available. A similar law has already been decreed by the government of French Tunisia, where the lube oil consumption is 6,000 tons a year. As a lubricant, olive oil is considered to be much inferior to mineral oil, and oil users are expected to make vigorous protest.

Petroleum Reserves

STRATIGRAPHIC VS. STRUCTURAL ACCUMULATION.—A. I. Levorsen, before Am. Assoc. Petroleum Geologists, Tulsa, March, 1936.

In this presidential address the author points out that petroleum geologists have achieved the confidence and trust of the oil industry almost entirely through their application of the anticlinal theory to the problem of oil discovery, and have attacked the business of locating anticlines, folds, and local deformations most energetically. The development of methods for detecting structural irregularities has been marvelous; aerial photography, the torsion balance, and other equipment of geo-

physics have done wonders in locating and describing anticlines, synclines, faults, domes, and other structural features even down to depths of 10,000 ft. As each method of structure hunting was developed it provided a sufficient number of new fields for exploitation so that current needs for petroleum were met. But, as the author facetiously remarks, the explorer for oil is apparently approaching a real danger of an oversupply of geophysical methods and an undersupply of anticlines. The fact appears to be that the oil operators, executives, and managers of oil companies have been led to believe in the magic of the closed contour until it is quite generally accepted that our future reserves are largely limited by the extent to which the geologists can find new domes and anticlines. "But if we are to depend on folding alone, our future discoveries are indeed limited, for we are undoubtedly running low on the supply of untested domes and anticlines."

If the supply of closed contours is giving out, where are we to find the 1,000,000,000 bbl. of oil per year which the United States will need for many years to come? The suggestion is made that less emphasis be placed by geologists on structural oil traps and more emphasis on stratigraphic oil traps. A stratigraphic oil trap is provided by a wedging or pinching out of the sand or porous reservoir rock, or a lateral gradation of sand from shale to limestone, or an uplift, truncation and overlap, or some similar variation in the stratigraphic sequence. A good example is the East Texas field, where the eroded upper edge of a sand lens has been sealed by subsequent deposition of an impervious formation. It is a fact that over half of the oil production from 22 of the largest oil pools of the United States has come from such stratigraph oil traps, and that most of them were discovered more or less by accident.

The implication is that the discovery of great pools like the East Texas pool is still possible. There is hardly a producing or nonproducing district or state from Pennsylvania to California underlain by sedimentary rocks in which untested porosity wedges are not present, and in many places they can be shown to be on a scale equal to that of the East Texas area. The future of the oil supply now depends on how well these stratigraphic variations are explored and exploited.

East Texas: The Largest Oil Reserve.—B. Mills, in OIL WEEKLY, vol. 80 (1936), No. 10, pp. 17–25.

The East Texas field was discovered in October, 1930. Early estimates placed the recoverable oil at 1,000,000,000 bbl., but rapid development that roughly outlined the producing limits of the field forced an upward revision that gave the petroleum industry a better idea of the economic importance of the discovery. Prior to completion of the first thousand wells, 2,000,000,000 bbl. was considered a conservative ultimate recoverable figure, but rapid extension of the field on all sides forced the indicated total to 3,000,000,000 bbl. Very recently a reliable engineering report placed the ultimate recoverable oil at 4,000,000,000 bbl., of which less than 25 percent has been produced.

The amount of oil ultimately produced by the East Texas field will depend largely upon the manner of operation and the rate at which production is obtained. If the field is sensibly produced throughout its flowing life, an ultimate recovery of 4,000,000,000 bbl. is possible. The time element must be considered, however, and from a short-range standpoint the 3,000,000,000 bbl. ultimate may be used.

As of January 1, 1936, the extent of the field has been estimated at 140,000 acres but more conservative figuring puts it at about 129,000 acres.

Methods of Estimating Underground Oil Reserves.—V. Bilibin, preprint of 17th International Geological Congress, 1937; 24 pages (in English).

In this paper, which is to be presented to the International Geological Congress that meets in Russia in 1937, the author (chief petroleum geologist of the U.S.S.R.) proposes a method of estimating oil reserves. The scheme classifies oil reserves as Prepared, Explored, Visible, Supposed, and Possible, and suggests methods of estimating to be used in evaluating these various categories by curves and various other means. An interesting use is made of the theory of probability in determining the magnitudes of reserves. The author invites correspondence with oil geologists who are preparing reports or papers in this field. His address is Moscow, Cpetenka 8.

Petroleum Economics

Air Traffic in the United States.—Oskar Tokayer, in PETROLEUM PRESS SERVICE, vol. 3 (1936), No. 11, pp. 84–85.

Figures published by the U. S. Department of Commerce show that there was a spectacular advance in air transport in the United States last year. Comparing 1935 with 1933 figures the actual mileage flown rose by only nine percent, but the number of passengers carried increased by 40 percent, and the quantity of freight (exclusive of mails) carried by air lines increased 100 percent. This is largely explained by the increase in the size and capacity of the airplanes comprised in the fleets of leading air transport companies.

The express goods services of the American air transport companies are now operated in conjunction with the railway services. It is stated that, as a result of a recent unification of air transport services, the total mileage over which they are available has been extended by 80 percent and such services now embrace 215 airports in the United States, which are served by 500 transport planes owned by 22 different air lines.

General

Protection of Iron by Phosphatizing.—May, in OEL UND KOHLE, vol. 12 (1936), No. 12, p. 255.

Attention is called to the growing use of phosphoric acid as a cleaning agent and rust preventive for iron or steel surfaces. Heretofore the objection to the use of mineral acids (such as hydrochloric or sulphuric acids) for removing rust and scale from iron preparatory to applying a protective coating of paint has been the difficulty of removing the last traces of the acid from the fine cracks or pores in the metal surface. These traces of acid remain to form soluble iron salts which pass into a spongy form (for example, iron sulphide) that later causes the paint to scale off.

The use of phosphoric acid for pickling purposes avoids this difficulty. Being a comparatively weak acid, phosphoric acid has little direct action on the iron but effectively loosens rust and scale, and when in contact with the metal forms a thin layer of insoluble iron phosphate which is inert and rust proof. In this way it is said that the surface of iron containers may be prepared for painting without an expensive, and often ineffective, mechanical treatment.

Testing Decolorizing Earths in Regard to their Susceptibility to Activation.—M. Krajcinovic and E. Cerkovnikov, in CHEMIKER ZEITUNG, vol. 59 (1935), p. 716.

When a dry fullers' or other adsorbing clay is mixed with oil of turpentine, there occurs an energetic exothermic reaction which can be used to compare the adsorptive activities of different clays and to predict their susceptibility to activation by acid treatment. In applying this test, one gram of the clay is mixed with five grams of oil of turpentine in a well insulated tube, and the resulting rise in temperature measured. In some cases only ½ gram of the clay is sufficient to raise the turpentine nearly to the boiling point. Small quantities of moisture in the clay decrease the thermal effect. The method is useful for purposes of comparison and also for ascertaining the optimum temperature at which the clay may be activated by heat.

Oil Self-Sufficiency and War.—Oskar Tokayer, in PETROL. PRESS SERVICE, vol. 3 (1936), No. 3, pp. 17–18.

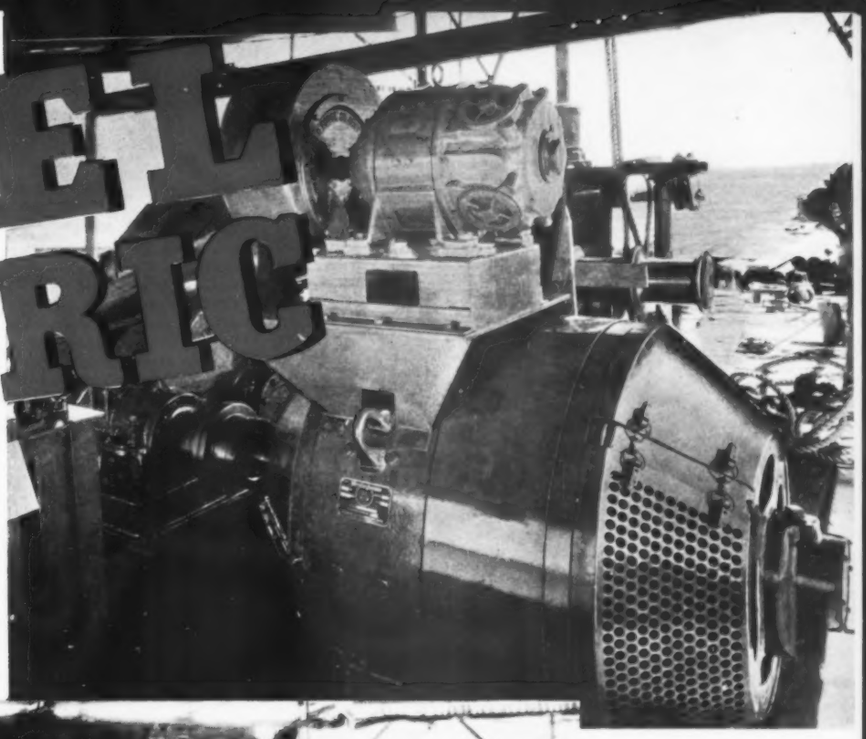
It is pointed out that even if the League of Nations should succeed in putting an absolute embargo on oil shipments to Italy, the result would be nearly negligible so far as the world oil trade is concerned, as Italy's oil requirements, even at their highest war level, are less than one percent of world consumption.

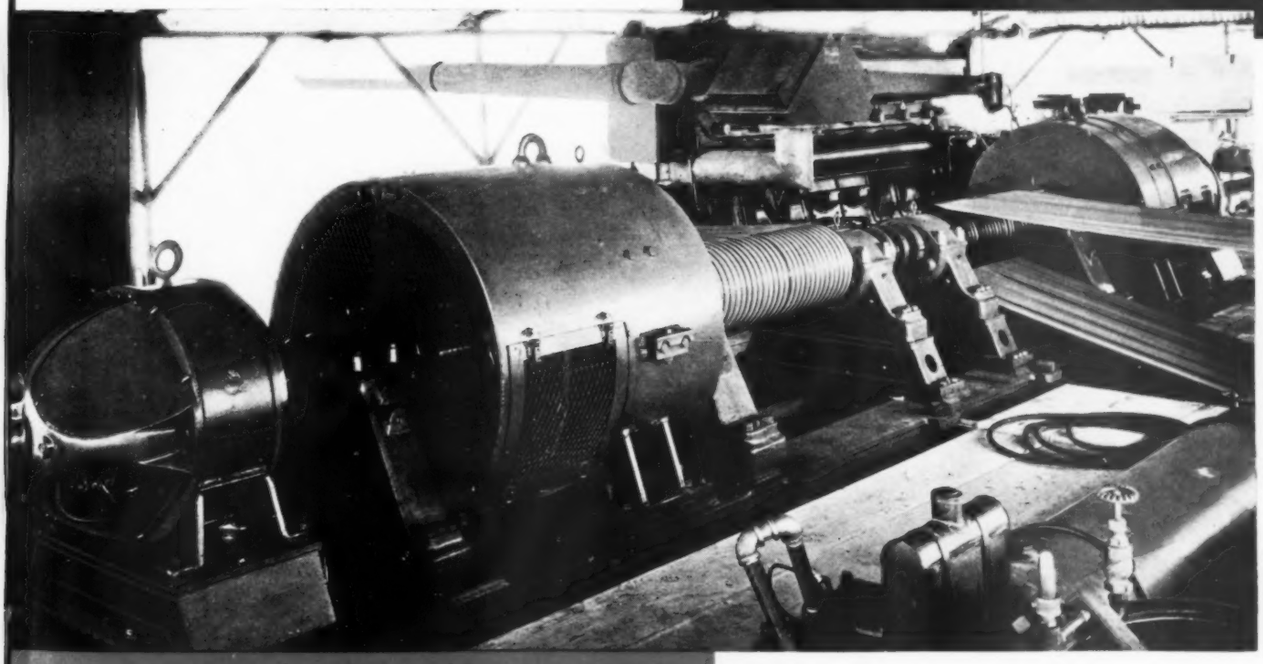
A matter of much greater importance for the oil industry is the effect which the whole sanctions controversy is having upon the motor fuel policy of non-producing countries, an effect which, unfortunately, is unlikely at this stage to be modified by any decision at Geneva. For the course of events has already led throughout the length and breadth of Europe to an almost hysterical demand, in the press and elsewhere, for a policy of self-sufficiency in regard to sources of war material. At no matter what cost, it is urged, the nation must not be faced, as Italy is, with an oil shortage in time of war.

And yet the hopelessness of a policy of self-sufficiency as regards motor fuel is strikingly demonstrated by the example of Italy itself. Much effort has been expended to obtain motor fuel from home-produced materials, but the results have been practically negligible. Italy's supply of substitute fuels would not carry the country through a fortnight, even if it were technically possible to run on such fuels. The same may be said of France, where the home produced motor fuel is utterly inadequate for wartime requirements, and where there has been established, at enormous cost, a national refining industry which, apart from its uneconomic basis, would in wartime place

DIESEL ELECTRIC

Will do it...





A Westinghouse 200/400 H.P. direct current drilling motor and type OP-1250 gear unit on a Rowan Drilling Company well at Monument, New Mexico.

Westinghouse 200 K.W. generators and exciter on a Parker Drilling Company operation near Perry, Oklahoma.

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the country in no better position than if it depended on imported oil products.

Germany, with its somewhat limited oil deposits, its wealth of coal and its production of benzole and alcohol, is considerably better off in the matter of substitute fuels than France or Italy. But even this partial German success has been obtained at enormous cost. The country is spending hundreds of millions of marks annually in manufacturing substitute fuels to cover half its requirements; that is, many times the amount required to pay for the entire imports of petroleum products.

It is difficult to understand how military preparedness can be better served by costly schemes for the production of substitute fuels than by the building up of adequate stocks of imported oil products purchased at the most favorable moments—a process not only possible and logical but also infinitely cheaper.

Mobile Military Lubricating Oil Recovery Unit.—Felix K. Mauler, in PETROLEUM, vol. 32 (1936), No. 3, pp. 1–4.

The author describes a plant for regenerating used lubricating oil which can be mounted on a steam powered truck and moved from place to place. One use of such equipment is to serve motorized troops (tanks, trucks); the prospective supply of oil in Germany in war time being none too large, the strictest economy is to prevail even during hostilities. The traveling oil regenerating unit can burn any sort of fuel for steam raising purpose, and it will have plenty of steam for the refining process.

Aluminum in the Oil Industry.—Anon., in OIL & GAS JOUR., vol. 34 (1936), No. 40, pp. 42–44.

Aluminum has many possibilities of use in the oil industry owing to the several demands this industry places on structural materials. Production equipment, particularly that which handles sour crudes, containing hydrogen sulfide, suffers a rapid turnover. The life of such equipment may often be prolonged by constructing it of aluminum.

While aluminum resists salt water under some conditions, it is not so well suited to handle brines as they occur in crudes fresh from the well. Hence aluminum is not as a rule used in drilling equipment.

A different situation prevails in flow tanks, lease tanks and storage tanks. The brine does not change much in character except for becoming more aerated, but it does settle to the bottom of the tank. Aluminum may be used in the sides and roof of the tank to take advantage of its high resistance to hydrogen sulfide. Not only will the life of the aluminum parts be longer, but so will that of the steel bottom. If the upper part of the tank is aluminum no sulfides are formed, and the corrosion of the steel bottom is no longer accelerated by electrolytic action.

Aluminum has been used not only for the sheet parts of the tanks but for the ladders, manhole rings, cast fittings, and thief hole covers. Aluminum sheet has also been used as a sheathing for wooden tank roofs.

Incorporating aluminum to the fullest practicable extent in the tank structure will considerably increase the initial cost, but the life of the tank will often be increased in an even greater proportion. When this is the case, the economy of aluminum construction is readily apparent.

When the oil reaches the refinery corrosion problems are less severe, except when sour crudes are being handled. In such cases, aluminum has been used to advantage in heat exchangers, gas lines handling corrosive gases, absorbers, condensers, bubble towers and bubble caps. Experience with cast aluminum bubble caps has shown that if they are of the proper composition and quality they will last much longer than other caps in certain types of service. Other refinery uses include tank breathers, flame arrestors, and floats and chains for tank gauges.

The light weight of aluminum plays an important part in such applications as portable lease buildings and small portable houses for survey and exploration. The high electrical conductivity per unit weight of aluminum cable, steel reinforced, accounts for its extensive use in telephone lines operated in conjunction with pipelines. The light weight of aluminum is the principal reason for its use in gasoline tank trucks, and to a more limited extent in tank cars. Aluminum has a quality which makes for safety around gasoline—it will not throw sparks when struck.

A great deal of aluminum has been used in the form of foil for coating various types of tanks. Since the foil reflects the sun's rays, the accumulation of heat during the day is reduced. Also, the bright metallic surface has the property of emitting heat by radiation at an unusually low rate. Hence the contents of the tank do not cool off much at night. This means that there will be less breathing in a foiled tank and less loss by evaporation. The foil also prevents corrosion to a considerable extent and in this respect provides some of the advantages of all-aluminum construction at low initial cost.

Alcohol-Gasoline Fuel

Alcohol Gasoline in Motor Fuel.—Gustav Egloff and J. C. Morrell, before Am. Chem. Soc., Kansas City, April (1936).

Alcohol-gasoline is a distinctly inferior motor fuel in performance, consumption, and upkeep of motor. Difficult starting, slow acceleration, overheating of engines, and rougher driving can be expected. Increased maintenance cost will result from cylinder and valve wear, all-around corrosion, plugging fuel lines, and dissolving of car varnish. Higher antiknock properties result from blends. Increased fuel consumption will be 60 percent of the volume of added alcohol. Economically, blending can result only in economic loss to society, and additional unestimated losses will result to the country at large from the political, moral, and health hazards.

The Performance of Engines with Gasoline and Alcohol as Fuels.—L. C. Lichty and E. J. Ziurys, before Am. Chem. Soc., Kansas City, April (1936).

This paper deals with the power, fuel consumption, and other performance characteristics of internal combustion engines when using gasoline and ethyl alcohol as fuels. Theoretical analysis shows ideal possibilities ranging from 2.0 percent increase in power with gasoline compared to pure alcohol, to 8.6 percent increase with pure alcohol compared to gasoline, depending upon mixture conditions.

The water in 190 proof ethyl alcohol is shown to have negligible effect on power and fuel comsumption.

Tests on a variable compression single-cylinder C.F.R. engine and on a 1935 Chevrolet engine under various conditions show a small average increase in power (not much more than experimental error involved) in favor of the 190 proof alcohol. However, the specific fuel consumption with 190 proof alcohol is about 60 percent higher on a weight basis, and about 50 percent higher on a volume basis than with gasoline.

Alcohol-Gasoline Blends.—Leo M. Christensen, before Am. Chem. Soc., Kansas City, April (1936).

During the past fifteen years there has been a very rapid expansion in the use of alcohols in motor fuel. Ethanol is most commonly used but methanol, isopropanol, and isobutanol have also been studied and to a small extent have been commercially employed, particularly in the formulation of racing fuels. Ethanol-gasoline blends containing 5 to 25 percent of anhydrous ethanol by volume are the fuels most commonly used. These blends are used interchangeably with gasoline of equal antiknock value and have found favor among consumers. The economic status of ethanol used in these blends is established by its antiknock value and other favorable properties rather than by its value as a fuel alone. In many countries the economic analysis must also give consideration to the importance of power alcohol to agriculture and labor, its bearing upon national self-sufficiency, its relation to dwindling petroleum supplies and other national economic and sociological problems. There are no technical obstacles in the way of a large power alcohol development in the United States and there is little doubt that such a program will develop. There are, however, problems in the establishment of adequate acreages of suitable crops and others of similar nature which will have to be worked out during the first stages of the development of a power alcohol industry.

The Utilization of Ethyl Alcohol-Gasoline Blends as Motor Fuels.—Oscar C. Bridgeman, before Am. Chem. Soc., Kansas City, April (1936).

Technical aspects of blending alcohol and gasoline are discussed. In general no significant change in mileage occurs with 10 percent or less of alcohol. With 30 to 40 percent there is increased fuel consumption. With unchanged carburetor setting alcohol blends result in loss of acceleration. With 10 percent alcohol blend, acceleration can be retained by readjusting carburetor, increasing fuel oil consumption about four percent.

Depending on the properties of the gasoline, 10 percent alcohol increases octane number from two to ten units, but increases volatility to an extent that in hot weather the butane content of gasoline would have to be decreased about two percent. Alcohol with a slight amount of water will blend in summertime but not in winter. Condensation of water from air might produce separation of alcohol in an automobile tank. This is the most serious problem in handling alcohol.

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MEXICO

AN EVENT of more than passing interest to all those concerned with the Mexican oil industry was the announcement April 20 of the settlement of the long pending suit between the Compañia Petrolera Commercial and Compañia Mexicana de Petroleo "El Aguila," more familiarly known as the Mexican Eagle. The controversy involved ownership in the petroleum tract Amaztlan No. 113 in the State of Vera Cruz. The property is in an area that has been a heavy producer and has been operated by "El Aguila," a member of the Royal Dutch-Shell Group, for many years. The dispute concerned the legality of the title by which the company originally acquired the property.

The original plaintiffs in the case passed out of the picture long ago, their potential rights having been taken over by the Compañia Petrolera Commercial, organized by prominent Mexicans who had close relations with the government. By reason of this fact and because of events connected with successive court actions the case assumed much more interest than an ordinary lawsuit over a land title. It almost became an international incident last year when the Mexican Eagle was ordered to deposit in Mexico City $10,000,000 in gold as a guarantee of payment in the event that the case was decided against them.

The present settlement was reached through purchase by Mexican Eagle of the entire properties and rights of the Compañia Petrolera Commercial for a sum said to be 12,000,000 pesos. Representatives of the purchasing company assert that they had a very strong case and had no fear of submitting it to an impartial tribunal but it was considered a good tactical move to arrive at a settlement in order to clear the situation and to pave the way for a more favorable attitude on the part of public officials. General opinion here is that the amicable adjustment of the case is in itself evidence of a less hostile attitude toward the larger oil companies on the part of the government and to that extent represents an improvement in the situation. While the government was not directly a part to the suit, the existence of the claim undoubtedly prejudiced relations between the company and the authorities.

Against this one constructive development to which too great importance is not to be attached must be set the fact that labor disturbances still continue and apparently are being fomented by communist agitators who are more intent on making trouble than on obtaining fair treatment for the workers. A case in point is the strike against the Huasteca Petroleum Company and the demand for a raise in wages amounting to over 200 percent in the face of an increase of 30 percent granted last year and an offer of an additional 10 percent, and despite the fact that the price of gasoline has been reduced two centavos per gallon by order of the government, thereby reducing the ability of the company to pay.

Almost at the same time with the settlement of the Mexican Eagle case it was announced that the company had brought in a new well in the rich Poza Rica field in Vera Cruz. The well, which is known as Poza Rica 13, is reported producing 3,145 bbl. daily at a depth of 7,503 ft. This is the company's tenth producing well in the field which is mainly under its exclusive control and which it began developing three years ago.

An injunction granted by the federal supreme court in a case concerning the International Petroleum Co. against a Ministry of National Economy ruling is seen as a precedent regarding procedure in taking over lands and incorporating them in the national oil reserves.

Some years ago, the company asked the Ministry for confirmation of rights to the Herradura and La Canoa petroleum tracts in the Panuco zone, Vera Cruz, rights which it asserted it enjoyed by lease from the owner, Saturnino Viñas, prior to the new federal constitution of 1917. The Ministry granted the company a concession to exploit and explore the lands for 50 years, with the right to extend the franchise at the end of that term. At the same time it confirmed the owner's rights to the property and stipulated that if for any reason the company ceased working the tracts, property would revert to the owner for exploitation during the unexpired period of the company's concession. The company, it is asserted, ceased operating the property without advising the owner. Ministry, claimants charged, declared the property free and incorporated it in the national oil reserves.

Heirs of Viñas obtained an injunction against the action from a lower court. Ministry carried the case to the supreme court, contending that the heirs had lost their rights to the subsoil of the land. Upholding the lower court, the high tribunal ruled that while the amended petroleum laws only allow benefits to owners of concessions or franchises, this action applies only to matters arising after the enactment of the amendments; not to cases that arose prior to the amendments. Therefore, the court held, Viñas' heirs have rights to the oil lands and they cannot be incorporated in the national reserves.

The gasoline consumption tax yielded 5,293,723.27 pesos (about $1,450,000, U. S.) during the first two months of this year as compared with $3,591,375.93 pesos in the corresponding period of 1935, announces the Ministry of Communications and Public Works. Increase is attributed to greater highway motor traffic. More money from this source has enabled Mexico to expand greatly her road network, the Ministry says.

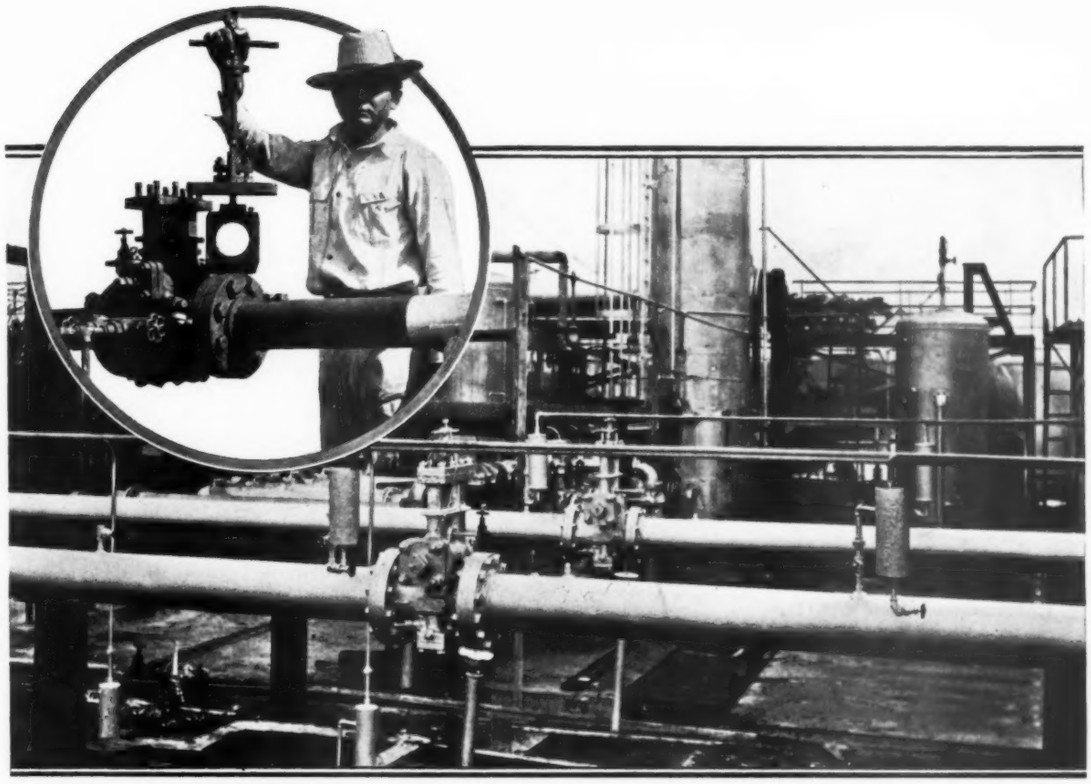
The Ministry of Finance announces the organization in Mexico City of two new petroleum companies. One is Compañia Mexicana de Petroleo Laguna with a capital of 1,000,000 pesos, composed of 20,000 shares worth 50 pesos each. This company has a five-year concession to exploit and explore petroleum lands and obtain and market oil and its by-products. The other enterprise is Compañia Mexicana de Petroleo Peco-Mex, with a capital 100,000 pesos made up of 1,000 shares valued at 100 pesos each. Its 30-year concession provides for buying and selling petroleum lands and oil products.

DOUGLAS GRAHAME

CANADA

THE Standard Oil Company of British Columbia, backed financially by its parent company, the Standard Oil Company of California, is considering the construction of a refinery in Saskatchewan to supply its own needs. The company already has bulk sales branches at Saskatoon and Edmonton. It entered the British Columbia field comparatively recently, and within a very short time gained control of seven percent of the oil business.

Nead Oil Refineries, Limited, of Toronto, Ontario, have made plans for the erection of a crude oil refinery at Owen Sound, Ontario. Work is to be started very shortly, although actually the refinery will not operate until next winter. The refinery will consist of a cracking unit with a capacity of 1,000 bbl. a day, aux-



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iliary equipment, and a coking unit. Gasoline will be produced, as well as coke and also a small quantity of fuel oil, in the following estimated annual amounts: gasoline, 2,500,000 gallons; oil coke, 6,000 tons; and fuel oil as required locally.

The balance sheet of Hargal Oils Limited, Alberta, shows current assets of $52,119, which includes investment in Royalite, Renfrew Royalty Company, and Butte I. X. L. at cost. Current liabilities are $48. Production operations of this company during the year under review were not spectacular, but non-operating income showed an improvement over last year. This was due mainly to profit on the sale of securities.

The annual report of North Star Oil Limited showed the net profit of the company in 1935 to be $103,873, which compared favorably with 1934's figure of $86,274. The company has 200,000 common shares outstanding as well as 200,000 shares of preferred.

Homestead Oil & Gas Limited are endeavoring to make arrangements for the marketing of gas from their well in the Bristol Valley field in New York state. The company holds 5,900 acres in the vicinity of the well.

Ambitious plans are being put into effect to explore potential gas and oil areas in the Turner Valley this year. Arca Development Company announced that an important test is to be spudded west of High River; another well is to be spudded in near the old Wabash test, west of Calgary; and the Northwest Company is going to spud in several wells on the Jumping Pound structure. Altoba Gas Company, affiliated with Canadian Western, Natural Gas, Light, Heat & Power Company, is planning to develop a new gas field.

Imports

DURING the month of February, 1936, crude petroleum imports into Canada amounted to 39,654,916 gallons, valued at $1,185,468. This compared with 61,131,349 gallons in January, 1936, and with 53,576,228 gallons in February of last year.

Gasoline imports amounted to 767,157 gallons, valued at $64,411, which compared with 1,041,100 gallons for January, 1936, and 716,952 gallons for February last year.

R. C. ROWE

▼

Tretolite Patents Held Valid

In a suit filed in Los Angeles by the Tretolite Company and the Tretolite Company of California, Ltd., two patents, involving processes for treating petroleum emulsions, were declared valid. California Production Co. was held to have infringed one of the patents by using a chemical, "Hydrate 488," for this purpose. The report of the special master recommended that the Federal District Court issue an injunction restraining the defendants and that an accounting of profits and damages be had.

UNITED STATES

	Daily Crude Oil Production bbl.	Daily Runs to Stills bbl.	Total Motor Fuel Stocks bbl.	Imports for Week bbl.	California Shipments East for Week bbl.
Week ending March 21	2,859,000 456,000[1]	2,815,000	73,157,000	870,000[2]	312,000
Week ending March 28	2,896,500 458,500[1]	2,765,000	73,012,000	1,026,000[2]	186,000
Week ending April 4	2,884,500 457,000[1]	2,690,000	73,871,000	801,000[2]	73,000
Week ending April 11	2,902,000 450,000[1]	2,755,000	73,654,000	1,468,000[2]	77,000
Week ending April 18	2,946,000 451,500[1]	2,795,000		1,033,000[2]	none

Underlined figures indicate improvement in statistical position—decrease in production, runs to stills, gasoline stock and imports.

[1] **Estimated total production of the East Texas field, official and unreported.**

[2] **Import figures include all oil imported, for domestic use and in bond for re-export, it being impossible to make the separation in weekly statistics.**

Huge Seasonable Demand Necessary to Maintain Prices

DURING the past month prices for petroleum and its products were fairly well maintained, but the accumulation of huge stocks of gasoline during the past winter made the price structure fundamentally weak and dependent upon the realization of hopes of refiners and marketers for a large increase in demand during the coming motoring season. It is generally conceded that there will be a major increase in motor fuel demand during the next few months, and that consequently accumulated stocks probably will be reduced, but the danger of the situation is that in the fall it will be impossible to reduce production to the economic levels which will be demanded at that time and that, accordingly, the price structure will be weakened. Anticipation of lower prices in the fall and winter will necessarily hold down any serious advance that might be justified during the coming summer. In fact, it is generally realized that it will be extremely difficult to reduce crude oil production and refinery runs in the fall and, therefore, the effect of that factor on the market must be necessarily considered in predicting crude oil and gasoline prices for the coming summer and fall seasons. In consideration of this, a crude oil price advance at this time or later in the spring is almost out of question. Similarly, any appreciable advance in gasoline prices is unlikely. It is unfortunate that unwarranted production and runs to stills took place during the past few months, because otherwise producers, refiners and marketers could have really benefited from the undoubtedly forthcoming huge demand of this summer.

Motor fuel prices remained virtually unchanged during the past month, though some weakness has been periodically apparent in this product. Natural gasoline declined ¼ of a cent per gallon in North Texas, but its price was maintained elsewhere. Kerosene quotations improved somewhat in the farming areas, but declined in the East. In the oil fields, Rodessa continued to be the primary disturbing influence, the state of Louisiana producing 50,000 bbl. per day in excess of the recommendations of the U. S. Bureau of Mines, while United States as a whole was producing, in the middle of April, some 150,000 bbl. per day in excess of the above economic quota.

During April retail prices throughout the United States improved slightly, while on the Pacific Coast a major upward readjustment took place during the first two weeks of the month. Tank wagon/service station motor fuel prices per gallon, regular grade, including all taxes, in representative districts at the end of April, were: 14.2/19.2 cents in metropolitan New York; 14.3/17.8 cents in Newark, N. J.; 12.5/16.0 cents in Boston, Mass. (off 0.5/0.5 cents per gallon); 12.0/15.5 cents in Providence, R. I.; 15.0/17.0 cents in Chicago (up 0.5/0.5 cents per gallon); 17.5/19.5 cents in Ohio; 17.0/18.0 cents in San Francisco (up 4.5/4.5 cents per gallon); 16.5/17.5 cents in Los Angeles (up 4.0/4.0 cents per gallon), with third grade gasoline selling at 15.0 cents; 15.0/19.0 cents in Oklahoma; 14.0/18.0 cents in Dallas and Fort Worth (up 1.0/1.0 cents per gallon); and 14.0/18.0 cents in Houston, with third grade gasoline in East Texas area selling

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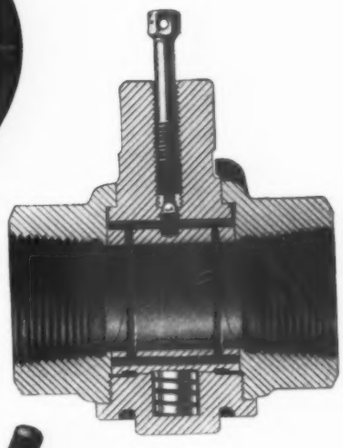

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unchanged at 12 cents to 13 cents per gallon at independent service stations; 15.7/17.7 cents in St. Louis; and 19.5/22.0 cents in Montreal, Canada; all with a 2-cent differential for the premium grade. The retail prices in the state of Texas improved considerably with the elimination of untendered gasoline in the Gulf Coastal area, where the Railroad Commission clamped down on a number of hot oil producers.

Refinery gasoline quotations in the Mid-Continent area remained unchanged, though the undertone was appreciably weaker during April. Refinery gasoline was quoted on April 20 at 5–5¼ cents per gallon for 58–60 U. S. M. grade, 62.9 and below octane rating in Group 3, Oklahoma market; 63.0–67.9 octane rating, U. S. M., regular grade, was quoted at 5¾–5⅞ cents per gallon; while 68 and above octane rating, U. S. M., was quoted at 6–6¼ cents per gallon. East Texas refinery markets continued unchanged during the past month, the third grade refinery gasoline eligible for interstate tenders being quoted on April 20 at 5 cents per gallon, while the gasoline restricted to intrastate commerce could be purchased for around 4 cents per gallon. On the East coast at Bayonne, U. S. M. grade, 60.0–64.9 octane rating gasoline continued unchanged during April at 6¾ cents per gallon (3.99 cents gold*). Gulf Coast quotations for export remained unchanged during April and on the 20th of the month, grade 58–60 U. S. M. was quoted at 5⅜–5½ cents per gallon (3.2 cents gold*).

Natural gasoline quotations were maintained during April in Oklahoma and Louisiana, but declined ¼ cent per gallon in North Texas, with the probability that the Texas cut will be extended to other areas. On April 20 grade 26–70 was quoted at 3–3⅛ cents per gallon (1.80 cents gold*) in Oklahoma; at 2¾ cents per gallon (1.62 cents gold*) in North Texas; and at 3⅜ cents per gallon (1.98 cents gold*) in North Louisiana.

Kerosene quotations advanced ¼ of a cent per gallon during the past month in the Southwest, because of the spring farm demand, but declined in the East. On April 20 grade 41–43 w.w. was quoted at 4⅜–4⅝ cents per gallon in Group 3, Oklahoma market; and at 4⅞ cents per gallon (2.88 cents gold*) on the East coast at Bayonne. Gulf Coast prices for export remained unchanged, and on April 20 kerosene was quoted at 3⅞ cents per gallon (2.92 cents gold*) for 41–43 p.w. grade, and at 4 cents per gallon (2.36 cents gold*) for 41–43 w.w. grade.

Fuel oil and furnace oil continued firm during the past month and on April 20 No. 1 p.w. grade furnace oil was quoted at 3⅞–4 cents per gallon and U.G.I. grade gas oil was quoted at 2½–2⅝ cents per gallon, all in Group 3, Oklahoma market.

Effect of Bureau of Mines Recommendations in Principal Oil-Producing States

(in thousands of barrels)

	March 1936				April 1936			
	Total Production	Percent of Total U. S. Production	Bureau of Mines Quota	Overproduction	Bureau of Mines Daily Quota	Daily Average Production Week Ending Apr. 4	Apr. 11	Apr. 18
Texas	34,840	39.5	34,220	620	1,123	1,137	1,140	1,155
California	17,560	19.9	16,720	840	553	562	574	574
Oklahoma	15,990	16.7	15,700	290	525	528	550	570
Louisiana	6,160	7.0	4,690	1,470	161	213	202	211
Kansas	4,610	5.2	4,400	210	146	152	149	148
Total United States	88,072	100.0	84,800	3,272	2,797	2,885	2,902	2,946

Gulf Export Prices for Major Oil Products

	Products	Cents per Gallon			
		Mar. 25	Apr. 1	Apr. 8	Apr. 15
Gasoline:	U. S. Motor	5½	5½	5½	5½
	64/66–375 E.P.	6	6	6	5¾
	59 Octane & below	5⅝	5⅝	5⅝	5⅝
	65 Octane & above	6⅛	6⅛	6⅛	6⅛
Aviation Gasoline:	73 Octane & above	10	10	10	10
Kerosene:	44 w.w.	4¼	4¼	4¼	4¼
	41–43 w.w.	3⅞	3⅞	3⅞	3⅞
	41–43 p.w.	3⅞	3⅞	3⅞	3⅞
Gasoil:	26–30 translucent	3⅛	3⅛	3⅛	3⅛
	30 plus translucent	3¼	3¼	3¼	3¼
Fuel oil:	Grade C Bunker (per bbl.)	$ .90	$ .90	$ .90	$ .90
	Cargo lots (per bbl.)	$ .80	$ .80	$ .80	$ .80
	Diesel oil (per bbl.)	$1.50	$1.50	$1.50	$1.50
Lubricating Oil: (New York Export Market)	Bright Stock No. 8	26	26	26	26
	Bright Stock No. 6½	25½	25½	25½	25½
	Warren E.	20½	20½	20½	20½
	600 Unfiltered	17	17	18	18½
	650 Unfiltered	18½	18½	19	19½
	600 Flash s.r.	19½	19½	20	20½
	650 Flash s.r.	24½	24½	23½	24
	Neutral 200 No. 3	27½	27½	27	27
	Neutral 150 No. 3½	23	23	23	23
So. Texas:	Red oil 300 No. 5–6	7¼	7¼	7¼	7¼
	750	9	9	9	9
	1200	9½	9½	9½	9½
	Pale oil 500	7⅞	7⅞	7⅞	7⅞
	750	9	9	9	9
	1200	9½	9½	9½	9½
Crude Oil:	East Texas crude delivered at Gulf port for Export	$1.37½	$1.37	$1.37	$1.37
	Venezuela crude	.83	.83	.83	.83
	Trinidad crude	.85	.85	.85	.85
	Panuco crude	.83	.80	.76	.75

Freight Rates

	Mar. 25		Apr. 1		Apr. 8		Apr. 15	
	Dirty	Clean	Dirty	Clean	Dirty	Clean	Dirty	Clean
(Shillings per ton)								
Calif.—U. K. or Continent	18/6	19/6	18/6	19/6	18/6	19/–	18/6	17/–
Gulf—U. K. or Continent	14/6	14/6	14/–	14/6	14/–	14/3	14/–	14/–
(Cents per barrel)								
Calif.—North Atlantic	85	85	85	85	85	85	85	—
Gulf—North Atlantic	25	21	22	23	22	23	18	18
Venezuela	23	—	23	—	22	—	20	—
Tampico	24	—	24	—	23	—	22	—

Imports and Exports

DURING February of 1936, total gross imports of crude petroleum and all its products into the United States amounted to 4,171,000 bbl. (144,000 bbl. per day), as compared with 3,563,000 bbl. (116,000 bbl. per day) imported during January; out of this total during February, 1936, 2,882,000 bbl. (99,300 bbl. per day) were imported for domestic use and 1,289,000 bbl. (44,400 bbl. per day) were imported in transit, either for refining and re-export or for use in vessels in foreign trade. During the preceding month, January of 1936, 2,421,000 bbl. (78,000 bbl. per day) were imported for domestic use and 1,142,000 bbl. (37,800 bbl. per day) were imported in bond, as indicated above. During February, 1936, the net imports for domestic use of 99,300 bbl. per day were 8.4 percent under the former federal recommendation of 108,400 bbl. per day, which was effective under the N.R.A.

Exports of crude petroleum and all its products during February, 1936, declined further, dropping 12.88 percent below the daily rate of the preceding month, amounting to 8,852,000

* U. S. dollar at 41 percent discount.

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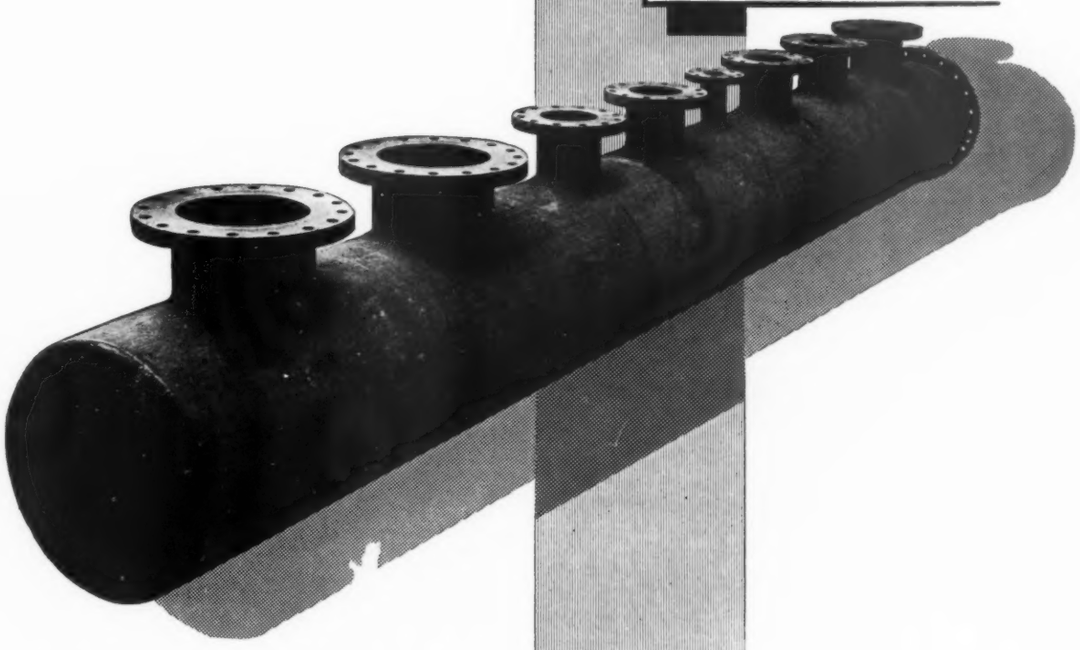

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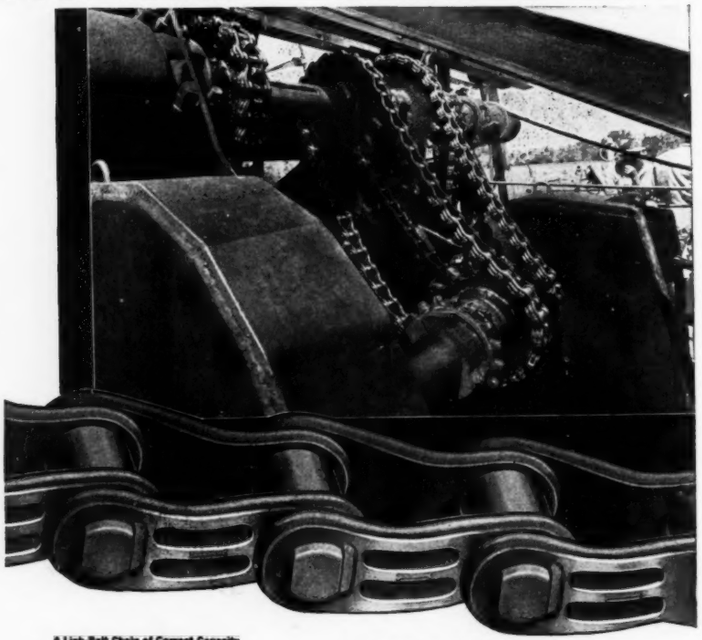

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SS-124, 2-Bar Hyper (API-4)	130,000
SS-40 Hyper (API-3)	75,000
SS-40+ Red-Hed (API-3)	48,000
SS-124+ Red-Hed (API-4)	112,000
SS-40 (API-3)	28,000
SS-124 (API-4)	60,000

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bbl. (305,500 bbl. per day), as compared with 10,162,000 bbl. (327,000 bbl. per day) which were exported during January of 1936. The low rate of exports during February is usual for this season of the year, and hence is not indicative of the export demand which may be anticipated during the coming months. The February, 1936, exports were 28.90 percent above shipments of February, 1935, when 6,634,000 bbl. (237,000 bbl. per day) were exported. Exports of crude oil from the United States during February of 1936 increased somewhat above the crude oil exports of the preceding month, and in February 3,474,000 bbl. (119,800 bbl. per day) were shipped, as compared with 3,067,000 bbl. (98,000 bbl. per day) exported in January of 1935, an increase of 22.2 percent; in February of 1935, 2,804,000 bbl. (100,000 bbl. per day) of crude oil was exported. In February of 1936, crude oil exports constituted 39.2 percent of the total exports of all petroleum products.

During January of 1936, the gross value of exports of crude petroleum and of all its products amounted to $20,138,262, as compared with the gross value of all petroleum imports of $2,766,319, leaving, therefore, a favorable balance of $17,371,943. Lubricating oils and greases led in the value of exports in January of 1936, being valued in that month at $6,161,211; followed by gasoline and natural gasoline valued at $5,120,919; followed by crude oil valued at $3,622,138; by fuel or bunker oil for vessels in foreign trade (not included in the domestic exports) valued at $2,576,851; by gas and fuel oil valued at $1,469,898; by residual fuel oil valued at $1,369,498; and by kerosene valued at $1,093,199. Of the fuel or bunker oil used by vessels in overseas trade, American vessels used 1,413,242 bbl., valued at $1,349,759, while vessels of other registry used 1,176,757 bbl., valued at $1,227,092. The above import figures include imports in bond, and after such imports valued at $915,742 are excluded, the net favorable balance for the United States for the month of January, 1936, was $18,287,685.

Crude Production and Runs to Stills Excessive

CRUDE oil and natural gasoline production during March of 1936 continued in excessive volume, reaching 2,975,000 bbl. per day, this production including about 20,000 bbl. of hot oil in Texas and Louisiana. The March, 1936, crude oil and natural gasoline production was 237,000 bbl. per day above the production in March of 1935, an increase of 8.64 percent. The largest proportion of the overproduction was derived from Louisiana, where production exceeded the quota by 1,470,000 bbl., or by 31.30 percent; this overproduction being in excess of the quota set by the U. S. Bureau of Mines, but within the state allowable as set by the State Conservation Commission, and hence not subject to the Connally hot oil act. In March California oil fields overproduced 840,000 bbl., or 5.02 percent, this being a radical improvement as compared with the preceding months. The state of Texas continued its excellent record in March by overproducing only 620,000 bbl. or 1.81 percent, while smaller overproduction was reported in Oklahoma and Kansas, which exceeded their respective quotas by 290,000 bbl. and 210,000 bbl.

Crude oil runs to stills during January, 1936, averaged about 2,800,000 bbl. per day, 11,000 bbl. per day under the runs to stills during the preceding month, when 2,811,000 bbl. were processed per day. Total stocks of petroleum products increased 1,583,000 bbl. during February of 1936 to a total of 542,918,000 bbl., indicating a daily gross addition to stocks of 54,500 bbl. Both crude oil production and crude runs to stills during the last three months have been at a rate much in excess of the economic volume, and have seriously undermined the price structure.

Motor Fuel Demand

INDICATED domestic demand for motor fuel during February, 1936, averaged 945,000 bbl. per day, 10 percent below the average during the preceding month, when 1,050,000 bbl. were consumed per day; the domestic demand during January, 1936, was only 1,000 bbl. per day above the domestic motor fuel consumption in February, 1935, a minimal increase, but it was 35,000 bbl. per day above the domestic motor fuel consumption of February, 1934, an increase of 3.84 percent. The low volume of

domestic consumption during February has been due exclusively to extremely unfavorable weather conditions in that month prevailing throughout the United States, and hence the maintenance of demand at the level of the preceding year is in itself a remarkably favorable indication. The preliminary figures for March and April suggest that the current domestic consumption is running approximately 10 percent above the preceding year, and if these figures will be confirmed by final reports, the excessive stocks accumulated during the winter may be appreciably reduced.

During February of 1936, 58,000 bbl. of motor fuel per day were exported from the United States, 30.1 percent below the motor fuel shipments of the preceding month; 17.8 percent above motor fuel exports in February of 1935, but 19.75 percent under the motor fuel exports in February of 1934.

On March 1, 1936, motor fuel stocks at refineries, plants, terminals and in transit, inclusive of natural gasoline, amounted to 65,657,000 bbl., an addition to storage of 3,044,000 bbl. as compared with stocks on hand on February 1, 1936, indicating that during February motor fuel supply exceeded demand by 105,000 bbl. per day.

Business Continues to Improve

THE New York Times weekly business index advanced during the first week of April to 97.3, the highest level it has reached since June of 1930, the advance being evenly distributed between the component factors. The stock market, which has previously already discounted the present improvement in business conditions, experienced a sharp set-back during the middle of April reflecting the general uneasiness in regard to political developments. The New York Times index stood at 86.0 on April 1, 1935; at 78.0 on April 1, 1934; at 68.0 on April 1, 1933; and at 69.5 on April 1, 1932.

Oil Field Developments Arkansas

THE most important news of the month came from South Arkansas where Phillips Petroleum Company's No. 1 J. D. Reynolds in section 27—T15S—R15W, located on the northeast flank of the Norphlet dome of the Smackover field, tested 50,000,000 cu. ft. of highly saturated gas from a total depth 4,908 ft., 12 ft. in a porous limestone of undetermined age. The north end of the Smackover field is cut off by the Smackover Graben faults, the fault on the south side of the Graben having a northward inclination of 45 deg., hence placing the top of the structure to the north with the depth. The new discovery appears to be of great importance and if it develops crude oil production with deeper penetration into the limestone topped at 4,896 ft. the Smackover field will be probably rejuvenated and add perceptibly to the present difficulties the industry is experiencing with the Rodessa field. Similarly commercial production in No. 1 Reynolds will start a major wildcat play which will cover the Graben fault zone of South Arkansas, which extends from R11W to R27W, a distance of about 100 miles.

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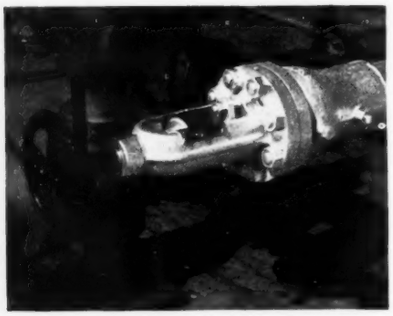
Rodessa—Louisiana

NEW completions during the past month increased the number of oil wells in the Rodessa field to 150, while there were in the field 60 active drilling wells and 25 active locations on April 30. The current allowable in the Rodessa field is 350 bbl. per well, or a total of 52,500 bbl. per day. Recent extensions on the Texas side of the field have increased the proven area of the field to 6,400 acres, while the total area may eventually reach 10,000 to 12,000 acres, suggesting a total cumulative recovery from the field of about 200,000,000 bbl. Two major deals took place in the Rodessa field during April. Standard Oil Company of Louisiana (S.O.N.J.) purchased from Haynes Drilling Company 3,000 acres of leases with 34 oil wells, 1 gas well and 5 drilling wells; the reported consideration was $5,000,000 in cash and $15,000,000 in oil payments. Magnolia Petroleum Company (Socony-Vacuum) bought the properties of R. H. Norton consisting of several wells and extensive undeveloped acreage on Louisiana and Texas sides of the field. The passage of these holdings into the hands of major oil companies has been almost inevitable because of high development costs in Rodessa.

BASIL B. ZAVOICO



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Official Figures for Soviet Oil Operations

1936	Crude Production (bbl.)	Daily Average (bbl.)	Runs to Stills (bbl.)	Drilling (feet)
January	16,500,000	532,290	14,000,000	513,700
February	15,400,000	531,435	13,600,000	460,000
March	15,940,000	514,200	13,860,000	580,000
Total 3 months 1936	47,840,000	525,573	41,460,000	1,553,700
Total 3 months 1935	40,206,600	446,740	31,228,700	1,032,618
Total last quarter 1935	48,190,500	523,810	40,339,400	1,363,382
Total 1935	176,688,100	497,713	146,705,100	4,868,465
Quota 1936	213,500,000	581,178	175,000,000	7,100,000
Quota 1935	212,310,000	581,672	171,500,000	5,214,000

Crude conversion: seven bbl. = one ton

DURING March the operations of the Soviet oil industry were divided into Stakhanoff decades in order to speed up results and appreciable improvements are reported from several divisions. Crude production for all fields is slightly below quota for the month, however, though several fields were operated at par and on individual days above plan, noticeably at Baku and at Ishimbayevo in the Urals.

According to reports on production, the daily plan fulfillment of all Baku oil fields has ranged from 97 to 102 percent. Individual properties, such as Stalin and Lenin groups, operated at between 101–106 and 104–107 percent respectively, but other Baku oil fields failed to live up to plans. The Lenin group of fields reported a total crude production of 7,258,000 bbl. for the first three months of 1936, or about one percent above quota. The total for all Baku fields for the first quarter 1936 is about 12 percent above the corresponding figure for the same period of last year. The total for all Soviet fields during the first quarter of 1936 was about 18 percent above figures covering the same period of 1935.

Production at Grozni during the month ran between 85 and 93 percent of the plan and evidently it became increasingly difficult to augment the total for all Grozni fields at the expense of Molgabek. This field, discovered some three years ago, has helped to check the decline of Grozni, which fell from some 8,500,000 tons in 1931 to about 3,500,000 tons per annum since that year. Grozni drilling operations have been considerably improved as regards distance drilled and speed of drilling attained, but there are, as yet, no visible signs of increased crude production. Percentage of plan attained by other Soviet fields was as follows: Maikop, 82–92 percent; Emba, 86–122 percent, and on individual days, 136 percent; Bashkiria (Ishimbayevo), 91–121 percent; Sakhalin, 67–94 percent; and Middleasia, 50–125 percent. All these fields show considerable fluctuation in production, indicating that flowing wells are responsible for the increases on individual days. Mechanized production is still a weak point at almost all Soviet fields with the possible exception of the Lenin or Stalin fields at Baku.

The refining division of the Soviet oil industry reports considerable progress. The refining trust of Baku has produced 100,000 tons of gasoline and ligroin during the first two decades of March against a quota of only 72,000 tons. Grozni refineries have produced 116,000 tons of gasoline and ligroin during the same period compared with a quota of only 90,000 tons. Soviet daily production of gasoline has increased from 8,900 tons in November to 9,800 tons in December, to 10,200 tons in January, to 10,500 tons in February, while the March figure has increased to 11,500 tons daily. For the first quarter of 1936 gasoline production showed an increase of about 45 percent over the first quarter of 1935, which, in turn, showed an increase of 2.5 percent over the first quarter of 1934.

Grozni refineries expect to produce during April 171,000 tons of gasoline and 152,000 tons of kerosene, which represents an increase of 21 percent in gasoline and 13 percent in kerosene over the corresponding figures for April of last year.

Plan fulfillment during March for the major Soviet Heavy Industries was as follows:

Coal, 97 percent; oil, 98 percent; pig iron, 100.2 percent; steel, 103.9 percent; rolling mills, 103.4 percent; copper, 87.6 percent; sulphuric acid, 104.8 percent; superphosphates, 111.3 percent; cement, 90.4 percent.

Interview With M. V. Barinoff

THE Soviet oil industry, nearing the end of the Second Piatiletka, is once again facing a cardinal reconstruction similar to the one undertaken in 1927–1928 before the beginning of the First Piatiletka. Once again Soviet representatives and key men of the oil industry have come to the United States to study progress and practice in American oil fields,

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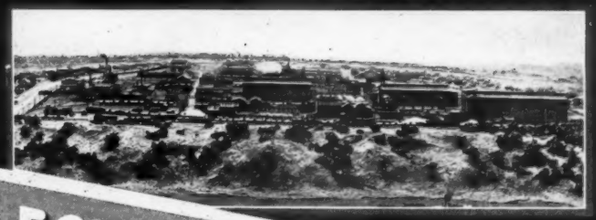
Diorama of the Monsanto, Illinois plant (model in perspective), in the lobby of Monsanto's administration building, St. Louis, Missouri



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The plan for 1935 called for an output of 97,000 tractors, 92,000 motor cars and 20,000 combines. The following figures compare the number of units of agricultural machinery in use September 1st, 1934 and 1935.

	Sept. 1, 1934	Sept. 1, 1935
Tractors (all types)	279,353	356,698
Motor trucks	30,221	51,549
Combines	33,308	50,822
Threshers (motor-driven)	30,804	38,227

The value of the yearly output of Soviet Heavy Industries has increased from Rbl. 21,200,000,000 in 1929 to Rbl. 27,800,000,000 in 1930, Rbl. 42,200,000,000 in 1933, Rbl. 50,-

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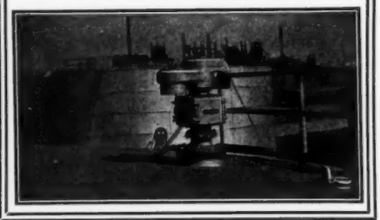

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000,000,000 in 1934 and Rbl. 58,500,000,000 in 1935. (One Rbl. equals 87¢ U. S.)

Mr. M. V. Barinoff, head of Glavneft, oil division of the Commissariate for Soviet Heavy Industries, is at present in New York in charge of a commission studying production and refining practice in the United States. He has been interviewed by this correspondent and has given the following outline of the Soviet oil picture:

For many years in the past Baku oil fields have produced the major portion of Soviet crude production and, together with Grozni and Maikop, the Caucasus have furnished almost 95 percent of the total Soviet crude supply. The Caucasian oil fields are situated near the Caspian and Black Seas and are connected with both seas by pipelines from Baku to Batum, from Grozni over Maikop to Tuapse, and from Grozni to Makhatch Kala. Thus they are in a favorable location for serving the export trade. During the years when internal consumption was secondary to exports, the industrial development of the country was still in the making and agriculture was rather primitive. The number of motor cars in use was negligible; trucks, tractors, combines and other farm equipment, together with motor transport and aviation, were problems of the future. Requirements for internal consumption were moderate and although the Caucasian fields are situated at geographical disadvantage as regards main industrial and consumption points, the existing system of transportation could, nevertheless, adequately handle the situation.

During both Piatiletka periods collective as well as state-owned agriculture has become industrialized and mechanized, and the industrial development of the country has assumed huge proportions. New roads, railroads, and air-routes have changed entirely the structure of the country. Deserts and steppe lands have been transformed into fertile areas; industrial plants have been erected and new cities have sprung up; new demands have arisen for oil products, and as the industrial geography of the country has changed it has become necessary to revise and redraw the oil-supply map throughout the Soviet Union.

In an endeavor to facilitate distribution, refining centers were built nearer the major areas of consumption. To process Baku crude refineries were erected along the Volga, and a pipeline was opened from Grozni to the Ukraine in order to open the flow of Caucasian oil to the industrial interior of the country. Production at Grozni, however, has declined alarmingly from 8,500,000 tons in 1931 to 3,500,000 tons. Nor can this deficit be made up by Baku, as Baku crude is of different specific properties. (Grozni crude has a high gasoline content.)

The resources of Grozni are not yet exhausted. The Molgabek field and other new regions of Grozni are under development. The fields of Baku are being extended to Aliati-Pirsagat, Kabristan Meadows, Prikurinsk, etc., the hinterland of which is the entire Azerbaidzan with as yet untapped vast oil resources.

During the past three or four years new discoveries of commercial value have been made in the Urals at Emba, in Middleasia, and along

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the banks of the Volga. The grade of crude from these fields is not inferior to Grozni crude; some of these crude grades are of high gasoline content, some are of a lubeoil base, while some have both properties. The geographical location of these fields, moreover, offers a favorable solution to the desired geographical redistribution of sources of supply in relation to main points of consumption.

Ishimbayevo in the Urals (Bashkirneft) will produce 1,000,000 tons of crude in 1936 and 2,500,000 tons in 1937. These fields, with a skimming plant in operation at Ufa and the Alco refinery already under construction, form an ideal source of supply for the industrial centers along the Volga and for Moscow, where a cracking combinate is to be erected with a capacity of 3,000 tons per day. The Volga Don canal, now being built, will provide a marine route for the transportation of Baku crude to Moscow. Cracking installations will also be erected at Odessa (Black Sea) and Kherson (Azov Sea).

The Emba oil fields, recently enlarged by the addition of Koschagil and South Iskin, are supplying crude to Orsk via a recently completed pipeline. Orsk is an industrial center in the east, beyond which are situated Khalilovsk, Magnitogorsk, Cheliabinsk, and Western Siberia. Emba's 1936 crude production quota of 600,000 tons will be considerably increased in 1937 and thereafter.

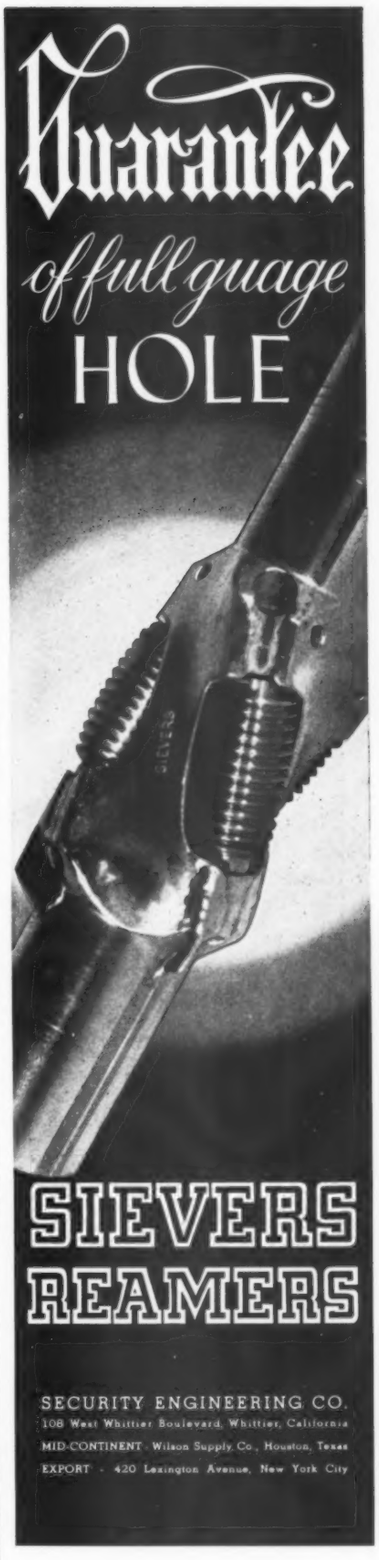
In Middleasia the Neftdag and Haudag fields, well known for their record flowing wells, form an ideal source of supply for the Soviet cotton belt, and the Sakhalin oil fields, with refineries at Khabarovsk, are to supply the Soviet Far East.

The Soviet Union possesses vast oil resources which are distributed over a large area of the country from the Arctic north to the Caspian Sea in the south, and from the Far East across Siberia, the Urals, and the Kalmuk steppe down to the Volga. The Soviets are making steady progress in the development of new oil regions more favorably situated, nearer to individual points of consumption and thus relieving the pressure of transporting Caucasian oil.

The decrease of Soviet oil exports during recent years is due to the sharp rise in internal consumption. Owing to the decline of Grozni production the supply of gasoline became limited and it was necessary to restrict exports in order to assure sufficient supplies for home consumption. Progress is being made, however, toward the readjustment of supplies and there is no doubt that sufficient oil will soon be available for export—perhaps in two years and perhaps earlier.

Progress in drilling, production and refining has been extremely encouraging and the domestic machine-shops have mastered sufficiently the technique of building oil equipment. However, the Soviet oil industry is always ready to place equipment orders abroad for all innovations developed in drilling, production and refining, and the Soviets are following, with keen interest, all new developments and production and refining practices in the United States.

J. WEGRIN



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